DEXTROSE LEVEL AND COOKING ENVIRONMENT AFFECTS ON WARMED-OVER FLAVOR OF BEEF TOP ROUND ROASTS

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CHAPTER I

INTRODUCTION

Convenience has become an important factor in many meal planning decisions. Quickly prepared "heat and serve" products are in demand. To stay competitive, the meat industry must continue to investigate methods to improve convenience. Precooking of beef roasts is a logical method for restaurants and food service operations to reduce preparation times and increase product utilization. Acceptance of precooked meats has been hindered by the production of off odors and flavors characterized by a rancid, stale or metallic flavor that develops during storage. These off flavors, commonly referred to as warmed-over flavor (WOF), were first recognized by Tims and Watts (1958) and identified as a form of oxidative rancidity that develops rapidly in cooked products. Although WOF will develop in fresh meat, it is more prevalent in meats which are cooked or processed by restructuring or grinding. Basically, WOF development is enhanced by any process which disrupts the integrity of the tissue membranes.

There are many proven antioxidants to reduce or inhibit WOF such as nitrite, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). However, consumers favor products with less chemical additives and with proposals such as California proposition 65 alternatives to BHA are actively being sought (Burditt, 1991) Proposition 65 states that "No person in the course of doing business shall knowingly and intentionally expose any individual to a chemical known to the state to cause cancer or reproductive toxicity without first giving clear and reasonable warning

to such individual." (Burditt, 1991). BHA was listed by the state of California as a chemical known to cause cancer, therefore, many companies are searching for alternatives to BHA.

The Maillard browning reaction is the result of a chemical reaction between proteins and carbohydrates and has been shown to have antioxidant properties. This reaction is enhanced with the application of heat and a decrease in moisture, conditions commonly found in food processing.

The carbohydrate constituent of meat is less than 1% of its weight, and is present mostly as glycogen or lactic acid. Thus, most meats are poor sources of carbohydrates, except those processed products to which sugar or other carbohydrates have been added (Judge et al., 1989). Dextrose, a polymer of glucose, is a reducing sugar that is readily used in the Maillard reaction and is a common ingredient in food products giving it a high consumer recognition. The research presented here involves the addition of dextrose to beef top round roasts in an attempt to increase the Maillard reaction and it's antioxidant effect. It was the intent of this study to determine the influence of added dextrose on the inhibition of warmed over flavor and the influence of extended holding times and cooking temperatures on its development. The first objective of this project is to determine the influence of 1% and 2% added dextrose on the inhibition of WOF in beef top round roasts. The second is to determine the influence of extended holding times on the development of WOF, and thirdly to note the effect of cooking temperature on the development of warmed-over flavor, in both whole and restructured beef top round roasts.

The fulfillment of these objectives will help to elucidate the practicality of adding dextrose to intact or restructured precooked beef roasts to deter WOF, and how different cooking environments affect the development of WOF as well as the product in general.

CHAPTER II

LITERATURE REVIEW

Lipids

Lipids and Oxidation

Understanding the development of warmed-over flavor (WOF) requires knowledge of the mechanism involved in lipid oxidation and the susceptibility of various lipids. The oxidative deterioration of lipids requires oxygen and involves mainly the unsaturated fatty acids, particularly the polyunsaturated fatty acids (Allen and Foegeding, 1981). Unsaturation is determined by the number of double bonds within the fatty acid chain. The polyunsaturated fatty acids, which have three or more double bonds and are associated with phospholipids, are most often involved with off flavor development in meat (Reineccius, 1979; Igene et al., 1979; Allen and Foegeding, 1981).

The first double bond of an unsaturated fatty acid commonly occurs between the 9 and 10 carbon atoms, counting from the carboxyl carbon. In polyunsaturated fatty acids, the double bonds tend to occur at every third carbon atom starting usually at C 9 and moving towards the methyl terminus of the molecule. Fatty acid double bonds almost always have cis configuration, which puts a rigid 30° bend in the hydrocarbon chain and interferes with their space filling packing (Voet and Voet, 1990). This consequently reduces van der Walls interaction, causing a decrease in the melting point of the fatty acid, with continuing effects with each additional

unsaturation. The bend in the fatty acid is also an easy access point for oxygen and thus lipid oxidation.

Unsaturated fatty acids are denoted by a numbering system consisting of two numbers, the first represents the number of carbons and the second represents the number of double bonds. The principal unsaturated fatty acids that make up the lipids of foods are oleic (18:1), linoleic (18:2), linolenic (18:3) and arachidonic (20:4). The oxidative breakdown of their unsaturated side chains involves a free radical mechanism, which is depicted in Figure 1 (Whitfield, 1992).

Initiation:	$RH + O_2$	------->	$R^* + {}^*OH$
Propagation:	$R^* + O_2$	------->	RO_2^*
	$RO_2^* + RH$	------->	$RO_2H + R^*$
Termination:	$R^* + R^*$	------->	RR
	$R^* + RO_2^*$	------->	RO_2R
	$RO_2^* + RO_2^*$	------->	$RO_2R + O_2$

RH is any unsaturated fatty acid, R* is a free radical, and RO_2H is a hydroperoxide that decomposes to form compounds responsible for off flavors.

Figure 2.1. Free Radical Mechanism

The primary site for oxidative attack is the methylene group adjacent to the double bond, with the initial step involving removal of a hydrogen atom from the methylene group. The resulting radical can rearrange before reaction with oxygen, leading to the formation of a number of different hydroperoxides. The hydroperoxides are subject to several further reactions forming secondary products. The peroxides may break down to carbonyls, form polymers or react with proteins (Karel, 1973). The range of different peroxides formed and the many different decomposition pathways available lead to a large number of volatile products from lipid oxidation including aldehydes, ketones, alcohols, esters, and acids (Whitfield, 1992).

TABLE 2.1

LIPID COMPOSITION OF BEEF

Type of fatty acid	Triglyceride	Phospholipid
Saturated (%)	45.2	32.9
Monounsaturated (%)	51.7	39.7
Diunsaturated (%)	3.1	12.0
Polyunsaturated (%)	0.0	15.5
Total unsaturated (%)	54.8	67.1

Data from Igene et al. (1981) are represented in Table 2.1 and shows the lipid composition of beef triglycerides and phospholipids. Triglycerides, generally referred to as neutral fats, are esters made up of a glycerol molecule backbone with three fatty acid components. Triglycerides function as energy reservoirs in the body and are therefore, the most abundant class of lipids. The fatty acid constituents of the triglyceride may be all the same fatty acid or mixed, and there is no specific order to their attachment to the three positions on the glycerol molecule.

Phospholipids are the major lipid components of biological membranes, they consist of glycerol-3-phosphate esterified at the C 1 and C 2 positions to fatty acids (Voet and Voet, 1990). In most animal tissues there is a marked tendency for saturated fatty acids to occur in position 1 and unsaturated fatty acids to occupy position 2 (Pearson et al., 1977). Membranes consist of a bilayer of mixed polar lipids with the hydrophilic heads oriented outward and the hydrocarbon chain, or hydrophobic end, oriented inward to form a continuous hydrocarbon phase. The structure of these lipids makes them quite susceptible to oxidation. Pearson et al. (1977) reported that the phospholipid fraction of meat is relatively constant while the fat content can be highly variable. These results are also in close agreement with

Dugan (1971) who reported that the level of phospholipids in meat range from 0.5 to 1.0%. Several studies (Tims and Watts, 1958; Sato and Hegarty, 1971; Igene et al., 1981) suggest that heating of muscle tissue makes the phospholipids susceptible to oxidation, and thereby accelerating the development of WOF.

Detection and Measurement

The detection and measurement of the extent of lipid oxidation is vital to the study of WOF and its inhibition. The 2-thiobarbituric acid test (TBA) is the most widely used test for measuring the extent of oxidative deterioration of lipids in muscle foods (Rhee, 1978; Gray and Pearson, 1987). The method of Tarladgis et al. (1960) involving steam distillation is the most popular method for measuring the TBA number in muscle foods, and has been used to study lipid deterioration related to warmed over flavor (Zipser and Watts, 1961; Sato and Hegarty, 1971; Sato et al., 1973; Wilson et al., 1976; Igene et al., 1981; Igene et al., 1985). Rhee (1978) recommended modification of Tarladgis et al. (1960) steam distillation method with the addition of propyl gallate and ethylene diaminetetraacetic acid (EDTA) at the blending process as the best modification to minimize further lipid oxidation during the test.

Malonaldehyde is a three carbon dialdehyde which is produced during the oxidation of unsaturated fatty acids (Kown and Watts, 1964). The TBA test measures the absorbance of the malonaldehyde-TBA complex at the wavelength region of 532 nm (Melton, 1983). This method has been reported to be highly related to sensory scores of oxidation and WOF in muscle foods (Zipser et al., 1964; Igene et al., 1979; Igene and Pearson, 1979; Greene and Cumuze, 1981). TBA numbers are usually presented as TBA reactive substances (TBARS) since other substances besides malonaldehyde (MA) react with TBA. Igene et al. (1985) showed that the

contribution to TBARS of MA in chicken was 80-90%, in correlation with other data showing MA to be 99.2% of TBARS in cooked pork, suggesting that MA is largely responsible for the pigment at 532 nm and reflects the rancid flavor development as indicated by sensory panel scores.

Malonaldehyde is a secondary product of lipid oxidation, but that does not necessarily mean that TBA values continue to increase throughout storage of meat. TBA values were observed to eventually decline during the frozen storage of cooked meats (Tarladgis and Watts, 1960; Igene et al., 1979). The decline in TBA numbers are thought to be the result of malonaldehyde reactions with other molecules of MA, proteins or vitamins (Buttkus, 1967; Karel, 1973; Gardner, 1979).

Proxidants

There are a number of things that can contribute to the extent of lipid oxidation, substances such as iron and environmental factors like temperature which tend to increase lipid oxidation thus working as proxidants. Catalysts to lipid oxidation include a variety of heme compounds which are generally accepted to accelerate meat lipid oxidation. An increase in cooked meat susceptibility to oxidation is due to a significant amount of non-heme iron released from bound heme-pigments upon cooking (Igene et al., 1979). Metal ions from heavy metals such as iron, cobalt and copper increase oxidation rates of food lipids. The basic function of the metal catalyst is to increase the rate of free radical formation (Pearson et al., 1977).

Temperature can affect lipid oxidation in many ways. Generally, the rate of the chemical reaction is directly related to temperature (Dawson and Gardner, 1983). A marked difference in TBA values between raw and precooked meat is evident both initially and after storage (Jantawat and Dawson, 1977). Cooking elevates the

percentage of phospholipids in relation to total lipids, and accounts for a significant increase in rate of lipid oxidation (Igene et al., 1979).

TBA values of raw samples are lower than those of precooked meat. Watts's (1962) explanation for this was that myoglobin in raw meat, when subjected to heat in the presence of oxygen, becomes denatured, releasing iron which can then act as a catalyst and initiate the oxidation of lipids after normal cooking and during subsequent storage. Also high temperature, as during cooking, could result in the breakdown of the lipid membranes, resulting in the release of lipids, now more susceptible to oxidative attacks (Igene et al., 1981).

Antioxidants

Just as there are proxidants which act to increase lipid oxidation there are factors that work to decrease or inhibit lipid oxidation and work as antioxidants. Labuza (1971) reviewed the kinetics of lipid oxidation in foods and classified antioxidant agents into three general types. Type I are free radical terminators, compounds which donate hydrogen to free radicals and thus stop the chain reaction. This group is comprised of phenolic compounds such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), the tocopherols and Maltol, a product of non-enzymatic browning. Type II are free radical preventers, compounds which control the production of free radicals during the initiation stage. Metal complexing agents which chelate metals are included in this classification, such as EDTA, citric acid and ascorbic acid. Type III are environmental factors, such as temperature and packaging materials, which influence the rate of oxidative reactions.

Maillard Reaction

The antioxidant effects of the Maillard reaction are the properties of the most interest to this research. While the Maillard reaction has been known to have antioxidant effects for some time, they have been overshadowed by stronger antioxidants such as BHA. With the current consumer trends away from chemical additives and with legislation like proposition 65 in California making BHA less appealing to producers, the antioxidant effects of the Maillard reaction are becoming a more attractive option.

The Maillard reaction is the most common chemical reaction occurring during food preservation and preparation (Mauron, 1981). The reaction is named after the French chemist Louis Maillard, who first described the formation of brown pigments of Melanoidins when heating a solution of glucose and lysine (Mauron, 1981). The positive aspects of the Maillard reaction are found in the production of desirable flavors and aromas, which undoubtedly contributes much to the enjoyment of eating. The negative aspects are the loss in nutritive value due to the loss of the amino acids used in the reaction. Concern also has been expressed on the possible formation of mutagenic compounds.

Mechanism of action

The minimum reactant requirements for the Maillard reaction are the presence of an amino bearing compound, usually a protein, a reducing sugar and some water. The Maillard reaction comprises a series of reactions that are far from being clearly elucidated. The following reactions are generally recognized with Glucose is used as the example in this reaction scheme (Fennema, 1985; Wong, 1989)

1. Formation of the glycosylamine, via a Schiff-base formation between the

carbonyl carbon of the reducing sugar, in open-chain form, undergoing nucleophilic attack by the amino nitrogen lone-pair electrons. This is followed by loss of water and ring closure. The reaction is reversible. The formation of the glycosylamine is acid-catalyzed and favored at low water content.

2. Amadori rearrangement in which the glycosylamine is transformed to the ketosamine. The nitrogen of the glycosylamine accepts a proton to form the amine salt, which is in equilibrium with the cation of the Schiff base (imionium ion). Rearrangement of the latter gives the enol form (1,2-enaminol), which then tautomerizes to yield the keto form of the Amadori compound. The tautomerization to the keto form is driven by the formation of the cyclic structure. The mechanism of Amadori rearrangement is catalyzed by a weak acid, and in the reaction involving amino acids, the carboxyl group of the amino acid may act as the catalyst by furnishing the necessary proton. If the initial sugar reactant is a ketose, a glycosylamine is formed by the same mechanism as for aldoses, but it undergoes a reverse Amadori or Heyns rearrangement to yield a 2-amino aldose.

3. Under acidic conditions, the Amadori compound exists in its salt form, the presence of the positively charged amino group assists in shifting the equilibrium to the enol form, which undergoes elimination of the hydroxyl group from C 3 to yield the 2,3-enol, which is readily hydrolyzed at the C 1 Schiff base to remove the amino group. Once the hydroxyl group has been eliminated at C 3, the course of reaction is not affected by the removal of the amino group.

4. Further elimination of the hydroxyl group at the C 4 yields glycosulos-3-ene.

5. The glycosulos-3-ene undergoes cyclodehydration to form furaldehyde.

The advanced stages of the Maillard reaction result in a dark brown nitrogen containing pigment (Melanoidins), and are believed to involve the formation of the

heterocyclic nitrogen compounds such as pyrazines, pyrroles and pyridines (Hodge, 1953) which appear to be largely responsible for the roasted , bready and nutty flavors of heated foods. A great number of heterocyclic compounds are formed during the latest stages of the advanced Maillard reaction. They include N-, S- and O-heterocyclic structures which play an important role as food flavors. (Hodge et al., 1972).

Among the N-heterocyclic compounds, much evidence has been accumulated indicating that pyrazines contribute directly to the roasted or cooked flavor of various foodstuffs (Maga and Sizer, 1973). They are typical products of the advanced Maillard reaction and have been reported in many heated food systems including beef products.

Influencing Factors

There are many factors that influence the speed and extent of the Maillard reaction. Water is absolutely necessary for the initial reaction to take place, but on the other hand it inhibits the browning reaction which comprises a series of dehydrations. When the moisture content is either zero or above 90% no browning is observed at all (Wolfrom and Rooney, 1953). Maximum browning appears to occur at 30% moisture (Wolfrom and Rooney, 1953; Fennema, 1985). In general, increasing water content or activity decreases the Maillard reaction.

Temperature and duration of heating are the most important criteria and, as noted by Mauron (1981), were first studied by Maillard (1912) himself, who reported that the rate of reaction increases with temperature. Cooking time and final product temperature appear to be the major factors influencing the production of Maillard reaction products (Huang and Greene, 1978).

Lowering pH decreases the Maillard reaction. Maillard browning is insignificant in strongly acidic solutions, since under these conditions, the amino group is protonated and consequently glycosylamine formation is prevented. Acid pH values inhibit and alkaline values accelerate the Maillard reaction (Underwood et al., 1959).

Only reducing sugars can take part in Maillard reactions as they provide the necessary carbonyl groups. The structure of the sugar affects the extent of browning, the greater the reaction the more browning that occurs. The hierarchy for browning being that pentoses, five membered rings, react more strongly than do hexoses, six membered rings, which in turn react more than disaccharides. The degree of pigment formation from a particular sugar is directly proportional to the amount of open-chain (free carbonyl) sugar in the equilibrium solution (Fennema, 1985). This strongly suggests that the amine reacts with the open-chain form.

Maillard reaction can be enhanced by copper and iron ($Fe^{3+} > Fe^{2+}$). This suggests that later steps in the Maillard reaction, perhaps those contributing to pigment formation, may be oxidation reduction reactions (Fennema, 1985).

Nutrition

The Maillard reaction effects the nutritional content of the product involved. When an amino acid or part of a protein chain reacts in the Maillard reaction it is obvious that the amino acid is lost from a nutritional standpoint. This loss is especially important for essential amino acids, of which lysine with its free e-amino group is most susceptible. Although loss of lysine is important because of its essentiality, other amino acids are also susceptible to degradation in Maillard browning. These include the other basic amino acids namely arginine and histidine. The basic amino acids are more susceptible to degradation than others because of the

presence of a relatively basic nitrogen atom in the side chain. It is useful to note that, if a food has undergone Maillard browning, some loss of amino acids and nutritive value must have occurred, even in the absence of the brown pigment (Fennema, 1985).

In addition to amino acid destruction, the Maillard reaction may also reduce amino acid availability indirectly through the formation of cross-links that reduce either overall protein digestibility or lead to the formation of biologically unavailable peptide residues that are absorbed but not metabolized (Ford and Skirrocks, 1971). The mechanisms by which the Maillard reaction reduces amino acid availability are:

Mechanisms
1. Blocking of amino acid side chains
2. Cross-links leading to absorbable but unavailable peptides
3. Reduced digestibility due to 1 and 2.

The most obvious negative consequence of the Maillard reaction in food is the loss of the nutritive value of the proteins. In general terms, this loss can be attributed to decreased digestibility or to the destruction and or biological inactivation (blocking) of amino acids. In the great majority of cases, however, the loss of nutritive value can be attributed to a loss in biological value due either to lysine inactivation as in milk products, or destruction of sulphur animo acids as in meat and fish (Bender, 1977). Loss of digestibility plays only an insignificant role when heating conditions are not extreme.

Mutagens

Nutritional content is not the only possible concern with the Maillard reaction, there has been questions raised as possible mutagen formation. In advanced stages of the Maillard reaction some mutagens might be formed (Kawamura, 1983).

Matsumoto et al. (1978) have reported on the mutagenicities of the pyrolyzed form of several peptides, proteins and amino acids, and significant mutagenic activity was detected. Pyrolyzed amino acids are cyclic compounds with five membered rings, like that of the pyrrole ring in the porphyrin ring structure of hemoglobin. The pyrolysis products required an activation with liver microsomes for their detection as mutagens. The highest mutagenic activity was observed with that of tryptophan containing peptides. It is important to note, however, that mutagenicity appeared only at temperatures above 400° C and was generally highest between 500° C and 600° C. Lee et al. (1981) conducted a 12 month feeding experiment of browned egg albumin with rats. Several changes were found, but no mutagenic response was observed. Meats appear to be particularly mutagenic compared to other food systems. The mutagens in cooked meats generally require metabolic activation and are mainly either carboline or imidazoquinoline derivatives (O'Brien and Morrissey, 1989)

Antioxidant properties

The Maillard reaction contributes much to food in terms of flavor, but it also has another very positive effect in terms of production of antioxidant components. The first report on antioxidative effect of Maillard reaction products (MRP) was made in the 1950's (Lingnert and Ericksson, 1981; Kawamura, 1983). Patton (1955) noted the contribution of the Maillard reaction in preventing dry milk powder from oxidation. Shortly afterward, Griffith and Johnson (1957) reported that the addition of glucose to cookie dough resulted in a better stability against oxidative rancidity during storage of the cookies. Improvement of antioxidative stability by heat treatment was observed by Anderson and coworkers (1963) in cereals such as wheat, corn and oats. Most of the work has been done on model systems. Some applications

in food systems have, however, also been reported (Lingnert, 1980; Lingnert and Lundgren, 1980).

Knowledge about the chemical structure of the antioxidative MRP is very limited. Only a few attempts have been made to characterize them. Evans et al. (1958) demonstrated that pure reductones produced by the reaction between hexoses and secondary animes were effective in inhibiting oxidation of vegetable oils. Eichner (1981) suggested that reductone-like compounds formed from Amadori rearrangement products could be responsible for the antioxidative effect of MRP. Yamaguchi et al. (1981) found most of the antioxidative effect in the melanoidin fraction. Possibly several different compounds formed by the Maillard reaction can exhibit antioxidative properties. Their formation might be dependent on what reactants are used and on the reaction conditions such as temperature, time, water content etc.

Lingnert and Ericksson (1983) studied the characterization of the antioxidants formed in the reaction between histidine and glucose in a model system. A constant observation when the MRP were separated by various methods was that antioxidative effect was found in many different fractions. Both the dialysates and the retentates from dialysis were antioxidative to some extent. This indicates that several antioxidative products are formed by the Maillard reaction, possibly differing in molecular size and chemical structure, but perhaps with one simple antioxidative function. Eichner (1981) claimed MRP to inactivate the hydroperoxides formed by the lipid oxidation. There are also reports on the complex binding of metals by MRP (Gomyo and Horikoshi, 1976).

Waller et al. (1983) conducted a study to observe the conditions for maximizing the yield of antioxidant products from the Maillard reaction. Increased pH from 4 to 9 increases the antioxidative products. An increase in antioxidative

activity was directly associated with an increase in the molar ration of sugar to amino acid and was favored by high total reactant concentrations and reaction temperature. Eichner (1975) indicated that low water activity favors the production of antioxidative browning intermediates more than it does the formation of higher molecular weight melanoidins. Although many of the antioxidants presently used by the food industry are effective in preventing rancidity, their safety is often questioned by the consumer (Waller et al., 1983). Most diets contain Maillard reaction products so the possibility of utilizing these as "natural" preservatives is attractive and should not be overlooked.

Warmed Over Flavor

The term "warmed-over flavor" (WOF) was coined by Tims and Watts (1958) to describe the rapid development of oxidized flavor in cooked meat. Since the report of Tims and Watts (1958), the definition of WOF has expanded to include raw refrigerated meat and cooked meat not rewarmed (St Angelo et al., 1990), it also develops in raw meat that is ground and exposed to air (Greene, 1969; Sato and Hegarty, 1971; Pearson et al., 1977). Since WOF is a barrier to the acceptance of precooked and fabricated meat products, its elimination represents a major challenge to the food industry (Love, 1988).

Inhibition of WOF development is of great economic importance and represents a challenge to a broad spectrum of the food industry (Graf and Panter, 1991). With increased consumption of precooked convenience meat entrees, such as quick-frozen meat dishes and TV dinners and an increasing need for fully or partially cooked meat to supply airlines, delicatessens, and fast-food restaurants, preventing the development of WOF has become of great importance (Pearson and Gray, 1983; Cross et al., 1987).

At the same time, the consuming public is becoming increasingly concerned about the use of synthetic additives in food products. The present trend in food processing is to use natural ingredients. Obviously then, a wise approach for retarding WOF is with the use of naturally occurring antioxidants or precursors whenever possible to retard lipid oxidation in cooked meat products (Bailey, 1988) such as with the use of Maillard reaction products.

The Model Meat System

To gain understanding of the mechanism of WOF development and lipid oxidation, Love and Pearson (1971) described the use of a model meat system to study the roles of different components. This system has been used by many researchers and so will be briefly explained here.

The model system uses bovine muscle which is ground and extracted with distilled, deionized water at 4° C until it is devoid of color, indicating the removal of the meat pigments, myoglobin and hemoglobin. Other water-soluble components would also be partially or completely extracted by this procedure. The remaining extracted muscle is then used as a model system to add back purified removed components and or other compounds to observe the effect each has on the system of lipid oxidation and WOF.

Mechanism of Development

The mechanism for WOF is essentially that of lipid oxidation. Phospholipids are the major lipids involved and studies have determined WOF is caused by lipid oxidation catalyzed by iron (Naskamura and Nishida, 1971; Love and Pearson, 1974;

Pearson et al., 1977; Pearson and Gray, 1983; Chen et al., 1984; St. Angelo and Bailey, 1987; Asghar et al., 1988).

Igene et al. (1979) demonstrated that the level of free Fe^{2+} greatly increased during cooking, and accelerated lipid oxidation in cooked meat. This indicated that myoglobin serves as a source of Fe^{2+}, being readily broken down during the cooking process and catalyzing autoxidation. Igene et al. (1979) also noted that treatment with hydrogen peroxide destroys even more of the heme pigments than heating, resulting in still greater oxidation of the meat system. These data are in agreement with the study by Rhee et al. (1987) that has shown that hydrogen peroxide and organic hydroperoxides release iron from heme proteins.

Studies have also shown that WOF is not solely due to lipid oxidation. There is strong evidence that reactions involving protein degradation may also be involved with WOF, particularly with the deterioration of desirable beefy flavor notes. Many of these reactions involve free radicals (Vercellotti et al., 1987; Spanier et al., 1988; St. Angelo et al., 1988). Thus evidence suggests that lipid oxidation reactions are catalyzed by iron and/or free radicals and these components are predominantly involved in development of WOF.

The study by Graf and Panter (1991) suggested a mechanism of site-specific radical damage in development of WOF in cooked meat. The mechanism involves the release of free iron from myoglobin or hemoglobin by a variety of thermal and redox processes prior to and during the cooking of meat. This free iron binds strongly to the negative polar head group of phospholipids. The iron-lipid complex catalyzes formation of oxygen free radicals which react rapidly with one or both of the phospholipid polyunsaturated fatty acid side chains. The result is a lipid peroxide that decomposes to malonaldehyde and other TBARS which are highly correlated with organoleptic WOF scores of meat and meat products. In their study they noted that

dissociation of the iron-phospholipid complex by iron chelation or cation exchange with polyvalent metal salts prevents this oxidative process and drastically inhibits WOF development. These results are in agreement with other studies which show antioxidants, particularly chelators, have been used successfully in inhibiting WOF development. In addition to chelator type compounds, free radical scavenger and oxygen binders have also been shown to be effective (Pearson et al., 1977; Pearson and Gray, 1983; St. Angelo and Bailey, 1987; Asghar et al., 1988).

Inhibition of WOF

The inhibition of WOF is essential in the production of precooked products. There are many compounds which inhibit the development of WOF, such and phosphates, ascorbates, nitrite, Maillard reaction products and other antioxidants like BHA.

Role of Phosphates. Tims and Watts (1958) showed that addition of phosphates to cooked meat protects against autoxidation. Sato and Hegarty (1971) verified the effects of phosphates in retarding the development of WOF by showing phosphate protected cooked ground beef against WOF during storage at 2° C. The phosphates appear to prevent autoxidation by chelating metal ions, such as iron and thus inhibit WOF.

Role of Ascorbates. At low levels (<100 ppm) ascorbic acid has been shown to catalyze development of WOF as shown by increased TBA values (Tims and Watts, 1958; Sato and Hegarty, 1971). At higher levels (>1,000 ppm), however, ascorbic acid retards oxidation (Sato and Hegarty, 1971). It has been suggested that high levels

of ascorbates may upset the balance between Fe^{2+} and Fe^{3+} or else could act as an oxygen scavenger (Pearson et al., 1977).

Tims and Watts (1958) showed that a combination of ascorbates and phosphates acted synergistically to retard development of rancidity. Sato and Hegarty (1971) verified the antioxidant activity of the combination. It has been shown that ascorbic acid and phosphates act synergistically in preventing oxidation of cured meat (Chang and Watts, 1949), and probably help in explaining the virtual absence of WOF in cured meats.

Role of Nitrite. Sato and Hegarty (1971) reported that 2000 ppm of nitrite completely eliminated WOF, while as little as 50 ppm greatly inhibited its development. A concentration of 156 ppm of nitrite has been shown to inhibit WOF development in cooked meat, with a twofold reduction of TBA values for beef and chicken and a fivefold reduction for pork (Fooladi et al., 1979). Zipser et al. (1964) proposed that nitrite forms a stable complex with the iron porphyrins of heat denatured meat, thus inhibiting WOF. Since non-heme iron has been shown to be the major lipid proxidant in uncured, heated meat systems (Sato and Hegarty, 1971; Love and Pearson, 1974; Igene et al., 1979), it seems more probable that nitrite stabilizes the heme pigments so that they do not release Fe^{2+} and thus catalyze development of WOF.

Role of Maillard Reaction Products. These compounds, usually resulting from the heating of various sugar amine mixtures, were first described as having antioxidant activity by Hodge and Evans (1957) and Evans et al. (1958). Hodge (1953) and Hodge et al. (1963) reported that various reducing compounds called reductones were produced during browning reactions. If this is true one would expect meat in combination with carbohydrate to be more stable against the development of

WOF which does, in fact, occur in meat loaves where carbohydrates are common ingredients (Sato et al., 1973). Certain products of the Maillard reaction are known to have antioxidant properties and are produced during retorting of meat. Zipser and Watts (1961) first described the development of an antioxidative effect in overcooked meat and suggested that diluted slurries could be used to protect normally cooked meats from oxidation. Sato et al. (1973) demonstrated that retorted meat possessed strong antioxidant activity against development of WOF. They showed that both the inhibitor and the precursors of the inhibitor are water soluble and readily extracted from the meat. They further showed that there was a relationship between antioxidant activity and development of the brown color.

Eichner (1981) has shown that browning intermediates, primarily Amadori rearrangement products, have strong antioxidant activity even though they are colorless. The mechanism by which these reductone and reductone-like compounds inhibit autoxidation seems to be by decomposing hydroperoxides and inactivation of free radicals (Eichner, 1981). Sato et al. (1973) have reported that reductic acid and maltol, which are browning products, possess strong antioxidant activity against WOF. Lingnert and Lundgren (1980) have demonstrated that Maillard reaction products inhibit oxidation of emulsion-type sausages.

In the work by Sato et al. (1973) browning reaction products obtained from the interaction of sugars and amino acids inhibit WOF development in cooked ground beef. Sugar-amino acid solutions which were not retorted and sugar or amino acid solutions retorted alone did not inhibit WOF development in ground beef. They found that reductic acid and maltol were very effective inhibitors of WOF development in cooked ground beef. Hodge (1967) reported that maltol is produced in typical Maillard-type reactions in foods.

A study by Lingnert and Lundgren (1980) tested preformed Maillard reaction products in sausages. All samples containing MRP were judged by a trained taste panel as less rancid even at the beginning of the experiment, as well as throughout storage. This is possibly due to some lipid oxidation occurring during the production of sausages without added antioxidants, while lipid oxidation in the other sausages was inhibited by the added MRP. The results point to the importance of applying lipid oxidation protection as early as possible in the manufacture of a product.

The inhibition of WOF by Maillard reaction products (MRP) was discussed by Bailey et al. (1987), who indicated that melanoidins and their precursors have strong antioxidant properties in the presence of lipid mixtures and could be important antioxidants for preventing WOF development in meat. Bailey (1988) tested MRP from a heated histidine-glucose mixture. When they were added at the .72% level they greatly inhibited the formation of oxidation volatiles and TBA reaction products of beef and pork. One of the intermediate compounds resulting from Amadori compounds during the Maillard reaction is maltol. Added at the level of .075%, this compound inhibited formation of WOF in cooked ground beef samples during storage at 4° C (Bailey, 1988). Since a major aspect of WOF is loss of desirable meaty flavor during storage, the production of MRP mixtures that can both produce desirable flavor and prevent oxidation during storage is highly desirable. Mann et al. (1989) noted that adding MRP may help maintain flavor over prolonged periods.

St. Angelo et al. (1990) studied the chemical and sensory aspects of antioxidant treated beef. They used the taste descriptor terms of Love (1988) to evaluate sensory characteristics by a trained taste panel. The most important descriptors are cooked beef brothy (CBB) which is the primary descriptor used to denote the highly desirable, freshly cooked, beefy flavor; and the main descriptors for

WOF were painty (PTY) and cardboard (CBD). Painty is known to be correlated very well with the volatile compound hexanal which is produced during lipid oxidation.

Maltol was one of the free radical antioxidants tested. The data indicated free radical scavenger compounds were effective in inhibiting PTY and CBD flavor and in retaining the high intensity of the CBB flavor. Free radical scavengers had greater flavor preservation effects then did chelators. Thus, antioxidants that function as free radical scavengers should be more acceptable as additives to preventing WOF formation and retaining desirable CBB characteristics than the chelators. These data also suggest that free radical chemistry plays a very important role in WOF development.

Their results (St. Angelo et al., 1990) indicated chelators and free radical scavengers could inhibit WOF in beef. Inhibitors that showed the smallest reduction in the CBB appeared to be those that act as free radical scavengers. Perhaps the free radical scavengers were serving two functions. they retarded or inhibited lipid oxidation, as well as protein degradation. Free radical chemistry obviously played a major role in the complex WOF process. An important aspect of this study was that it showed that a comprehensive sensory evaluation of experimental samples by trained panelists is vital, along with chemical or instrumental analyses when evaluating compounds as potential WOF inhibitors.

Other antioxidants. Chemical additives such as BHA and BHT have been shown to inhibit WOF (Greene, 1969; 1971). Chastain et al. (1982) showed the antioxidant effects of tertiary butylhydroquinone (TBHQ). EDTA has also been shown to have WOF inhibiting effects (Igene et al., 1979). Many chemicals have been shown to have antioxidant effects, their modes of action are generally thought to

be as free radical inhibitors, metal chelators or oxygen scavengers (Gray and Pearson, 1987).

Pratt and Watts (1964) demonstrated that extracts from a number of plant sources (green onions, green peppers, potato peelings, and green pepper seeds) are effective antioxidants for meat, particularly in precooked meals where combining vegetable extracts with meat may prove to be an acceptable procedure for retarding the development of rancidity.

Smoke is commonly used as a flavoring ingredient for cured meat. Part of its usefulness is known to be related to its antioxidant properties (Kramlich et al., 1973).

Detection Methods

The detection of lipid oxidation and WOF are similar in some respects, in that the Tarladgis et al. (1960) method for TBA is very popular for both. However, WOF is associated more with cooked products and the use of a sensory panel is associated more with WOF detection. The most popular detection methods for WOF are the trained sensory panel because as St. Angelo et al. (1990) displayed the use of a trained sensory panel is extremely valuable in evaluating WOF and also for evaluating antioxidants. The distillation method of Tarladgis et al. (1960) is also the most widely used method still today (St. Angelo et al., 1988). There are other methods, such as those involving the use of gas chromatography (GC) and high performance liquid chromatography (HPLC) technologies, which usually involve the detection of volatile compounds from lipid oxidation (Gray and Pearson, 1987; St. Angelo et al., 1990)

The TBA method of Tarladgis et al. (1960), has been used successfully by several investigators (Younathan and Watts, 1960; Keskinel et al., 1964; Greene, 1969; Witte et al., 1970; and Greene et al., 1971) to measure lipid oxidation in raw or cooked meats. Tarladgis et al. (1960) found that TBA numbers (mg TBA reaction

substances/kg tissue) were correlated highly with trained sensory panelists scores for rancid odor in ground pork. They also found the TBA number at which a rancid odor first was perceived by the panelists to be between 0.5 - 1.0. This "threshold" has served as a guide for interpreting TBA test results. According to a studies by Turner et al. (1954), Younathan and Watts, (1959) and Greene and Cumuze (1981), the TBA test can serve as an indicator of oxidized odor or flavor in meat when odor or flavor are judged by trained or experienced sensory panelists. The presence of malonaldehyde in meat, as measured by the TBA test, has been correlated with taste panel scores describing rancid flavors (Younathan et al., 1980, 1983; Greene and Cumuze, 1981; Igene and Pearson, 1979).

The study by Mann et al. (1989) showed that WOF was not detected by their taste panel until TBA numbers of 1.6 or greater for the meat samples were reached. This value is slightly higher than the 1.0 TBA number reported by Tarladgis et al. (1960) as the threshold for rancid odor detection. However, it is possible that the compounds added to the roasts in this study may have masked some of the off flavor. Younathan et al. (1980) reported agreement between TBA values and panel scores for cooked ground beef and other researchers have also noted significant correlations between TBA values and sensory scores describing rancid flavors or aromas (Gros et al., 1986; St. Angelo et al., 1990). A marked difference can be seen between trained and consumer (untrained) panels through a consumer taste panel study by White et al. (1988). Their data suggested that consumers, unlike trained panels, would not be able to detect differences in off-flavor between samples with a TBA number of 6.3 or lower and freshly cooked roast beef samples with TBA numbers of approximately 0.8.

Cross et al. (1978) described a method for which to train members for a taste panel as an effort to help researchers work on a more uniform basis. Panelists are trained in order to familiarize them with test procedures, improve the individual's

ability to recognize and identify sensory attributes, and to improve their sensitivity to and memory for test attributes, so that sensory judgments will be precise and consistent. Many descriptors have also been used to create uniformity and increase sensitivity, such as those described by Love (1988) and explained previously. Both of the descriptors, painty and cardboard, are the major off-flavor attributes associated with the WOF process (Love, 1988; St. Angelo et al., 1990). It is important to note that, as with the flavor volatiles and the TBARS, that sensory panels are able to clearly demonstrate that cardboard and painty flavor increase with WOF (Spanier et al., 1988).

Approximately 23 different volatile compounds increased in concentration during storage of samples (Bailey, 1988). Of the many compounds that increased during storage the most obvious was hexanal, a secondary reaction product of linoleic acid oxidation. Hexanal was the compound that increased the most rapidly during the development of WOF. An increase in hexanal can be detected with in 1 hr after cooking. This and some other compounds which also increases would serve as excellent markers to follow the development of WOF (St. Angelo et al., 1988) .

There are many reviews that repeatedly suggest that heterocyclic compounds such as those produced during the Maillard reaction containing oxygen, nitrogen, and sulfur are the principal constituents of meat flavors and aromas (Maga, 1975; 1982; Dwivedi, 1975; MacLeod and Seyyedain-Ardebili, 1981; Galt and MacLeod, 1984; Shahidi et al., 1986). Apparently, as WOF develops and lipid oxidation reactions increase to yield compounds that are present at ppm levels, the desirable beefy flavors heteroatomic compounds present at ppb levels are masked, their flavor contribution cannot overcome the off flavors being generated by the more abundantly present lipid oxidation by products (St. Angelo et al., 1988).

Cooking Treatments

The cooking of a food product, especially a meat product, has one of the most encompassing influences of any preparation or production factor. Cooking influences everything from flavor, color, tenderness, juiciness and also WOF development. A number of researchers have noted the accelerating effect of heating on the development of oxidative rancidity in meat and meat products (Younathan and Watts, 1959, 1960; Chang et al., 1961; Kesinkel et al., 1964; Sato and Hegarty, 1971; Keller and Kinsella, 1973). Cooked meat exposed to oxygen can develop off flavors in a matter of a few hours. Because of the free-radical chain reaction nature of lipid oxidation, any degree of the oxidation occurring in raw materials can accelerate the development of WOF or oxidized off flavors in cooked products (Igene et al., 1979; Rhee, 1988).

The influence of high temperature cooking of meat on WOF was studied by Huang and Greene (1978), who found that the WOF retarding activity of meat was enhanced by cooking at high temperatures (roasting, braising, pressure cooking, pressure canning). Sensory data also revealed that the liquid produced by pressure cooking of beef retarded WOF in both raw and cooked beef, which is in close correlation to results found by Sato et al. (1973) in terms of liquid dripping antioxidative effects. According to Pearson et al. (1977) experiments have shown that the development of rancidity occurs most rapidly in meat heated at 70° C for 1 hour , while the extent of rancidity decreased if the cooking temperature was raised above 80° C. It has also been shown that meats requiring a long cooking time have the greatest increases in TBA values upon cooking. Siu and Draper (1978) found a significant correlation between cooking time and increased TBA values.

Gros et al. (1986) conducted a study on the development of WOF on beef patties using microwave (MW) conventional oven (CO) and oven broiler (BR) methods. Immediately following cooking, the MW treated patties had a significantly ($P<.05$) lower mean TBA value than patties prepared by the CO and BR methods. This finding were in agreement with Newburg and Concon (1980) and Siu and Draper (1978). The lower MA production in the MW treated patties was attributed to their significantly shorter cooking time. MW and CO patties had the highest TBA values after refrigerated storage. The BR patties resulted in the greatest browning and after refrigeration, the lowest TBA values. Significant differences were found in panel scores for aromas due to storage time and for method of cooking. Regardless of cooking method, freshly prepared samples were rated as more desirable than refrigerated samples. Patties prepared by the MW received the lowest aroma scores in the freshly prepared and refrigerated states. However, there was no significant difference among cooking methods for flavor. Broiled patties received the highest mean panel scores both immediately following cooking and after refrigerated storage.

This finding suggest that antioxidative substances are produced during the browning process which decrease the rate of warmed over flavor development of the BR samples relative to those prepared by MW and CO, and or that the browning reaction may have imparted flavors that masked the off flavors and aromas present.

The quality of cooked meat during frozen storage was reviewed by Bailey (1988), who related that cooked meat can have an appreciable shelf life during frozen storage if precautions are taken to protect the product from oxidation. This might be accomplished through use of antioxidants and cover sauces, particularly those containing MRP used in conjunction with proper packaging.

Restructuring

Restructuring a product involves the reduction of particle size or comminution of the product, mixing of all ingredients involved, and reforming the product to a desired shape or size. Restructuring also influences the development of WOF. Although cooked meat is more susceptible to lipid oxidation than uncooked meat, oxidative changes in lipids can become a serious problem for uncooked meat when it is subjected to size reduction (such as grinding , flaking, and chunking), the grinding exposes a greater surface area to oxygen and disrupts the lipid membrane exposing the lipids to oxidation (Pearson et al., 1977; Rhee, 1988) . It may also aid in the break down of myoglobin to release free iron (Gray and Pearson, 1987). Restructured products are, therefore, highly susceptible to lipid oxidation and WOF problems.

Sato and Hegarty (1971) reported that WOF develops in raw meat within one hour after grinding and exposure to air at room temperature. The odor and flavor changes were accompanied by a large increase in TBA values. These authors postulated that any process causing disruption of the muscle membrane, results in exposure of the liable lipid components to oxygen, and thus accelerates development of oxidative rancidity. They also suggested that any catalysts of lipid oxidation present in the muscle system are brought into contact with the susceptible lipids and may also contribute to the rapid development of WOF.

Background

Research has been done in the area of WOF inhibition through the use of the Maillard reaction and its products. Most of the previous work in the field of inhibition of warmed over flavor through use of the Maillard reaction has been done with the addition of preformed Maillard reaction products (MRP), such as eluded to

earlier. Researchers, such as Lingnert and Lundgren (1980); Lingnert et al. (1983); Waller et al. (1983); Bailey (1988); and Mann et al. (1989); showed that the MRP did indeed reduce or inhibit WOF. Much of this research used the addition of the MRP to the meat as just another antioxidant. While this is the addition of natural products, a still more natural avenue is available, one which would not be listed on the label as an antioxidant or an additive per se, but as a common well known ingredient. Through the use of adding a carbohydrate constituent, such as dextrose or glucose to the meat and letting the Maillard reaction occur during cooking the antioxidant is formed with the addition of natural ingredients. There are some possible drawbacks to this approach, such as the consumer resisting added "sugars" in products, as well as the loss of some of the amino acid content in the meat through the Maillard reaction. Yet this process would appeal to the consumer's search for a label with more "natural" ingredients and less food additives.

The research conducted by Goll (1988) studied the addition of dextrose to restructured beef roasts. The scope of their research was to observe the effect of the added glucose with phosphate and or sodium chloride (salt) in two different internal temperature end points of 63° C and 93° C in pre- and post-rigor meat. They had four treatments, one without glucose consisting of 2% salt and 0.5% phosphate (SP); 2% glucose with 2% salt and 0.5% phosphate (SPG); 2% glucose with 2% salt (SG); and 2% glucose with 0.5% phosphate (PG). The restructured product was stuffed into casings and steam cooked in a smokehouse to the two internal temperatures and then cooled overnight in their own drippings. They found that the taste panel and TBA results were compatible and that the addition of the glucose to the salt-phosphate combination helped to hold down the WOF and TBA numbers, and were more acceptable to the taste panel during storage conditions. They also noted that the 93° C internal temperature roasts were more acceptable to taste panelists and had lower TBA

had lower TBA numbers than did the roasts cooked to the lower internal temperature of 63° C. Thus showing that the addition of glucose to a product will decrease WOF and that a product that is cooked to a higher internal temperature has a greater inhibition of WOF and a higher consumer acceptance.

The introduction of California's proposition 65 opened a Pandora's box of sorts. The proposition states: "No person in the course of doing business shall knowingly and intentionally expose any individual to a chemical known to the state to cause cancer or reproductive toxicity without first giving clear and reasonable warning to such individual". This leaves much up to interpretation as to what is a risk and what is clear and reasonable. In 1990 the state of California listed BHA as a chemical known to the state to cause cancer (Burditt, 1991). Therefore, costly analysis for BHA content and risk assessment would need to be done on all products containing BHA or a warning must be added to the label. Warning labels are notoriously not good for sales. Therefore, interest in alternatives to BHA has been on the rise. Other states, such as Ohio, have shown interest in legislation similar to Proposition 65 (Burditt, 1991). The trend for consumers desiring less additives in their food is becoming less of a compliance and more of a mandate.

Summary

Lipid oxidation is a deterioration process which occurs in all meat products and reduces its value and acceptability. This process can be controlled through the use of antioxidants such as BHA. Yet, the use of such additives to food products has come under scrutiny by consumers and with legislation like California proposition 65 has come under disfavor with many producers. Therefore, alternative antioxidants are on the increase.

The Maillard reaction is a non-enzymatic browning reaction occurring between reducing sugars and amino acids. The Maillard reaction has some effective antioxidant properties, and is a natural process in food products, especially cooked products. Therefore, the Maillard reaction and its products could be a viable alternative to BHA with a higher consumer appeal.

Warmed-over flavor (WOF) is an off-flavor produced in cooked meat as a result of lipid oxidation. WOF stands in the way of acceptance for precooked meat products, but can be controlled with the use of antioxidants. Therefore, the study of adding dextrose, a reducing sugar, to meat products to increase the Maillard reaction during cooking could prove dextrose to be an effective inhibitor of WOF and an alternative to the use of BHA.

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CHAPTER III

DEXTROSE LEVEL AND HOLDING TIME AFFECTS ON WARMED-OVER FLAVOR OF BEEF TOP ROUND ROASTS

Abstract

Precooking of beef roasts is a logical method of increasing convenience to both the consumer and food service operations, but has not been widely accepted due to off flavors that develop during storage. It was the intent of this study to determine the influence of added dextrose on the inhibition of warmed over flavor (WOF) and the influence of extended holding times on the development of WOF. Three brines were formulated with deionized water and injected into top round roasts to achieve a final concentration of 0.2% sodium chloride and 0.3% sodium tripolyphosphate and either 0%, 1% or 2% dextrose. Roasts were cooked to 54° C internal temperature and held at a temperature of 60° C for 2 or 6 hours. 2-Thiobarbituric acid (TBA) analysis showed that a significant reduction in WOF development occurred with the 1% and 2% dextrose treatments over a 5 day storage period, with the 2% dextrose level being more effective than the 1% treatment. WOF was also inhibited over holding times with 2 hours holding having higher ($P<0.05$) TBA values than the 6 hour holding time. Warner-Bratzler shear force indicated no differences ($P>0.05$) between dextrose treatments, however, shear force did increase with increasing holding time. Proximate analysis showed all dextrose treatments to be similar in fat and moisture content, and that the 6 hour holding time has significantly lower moisture. The inclusion of

dextrose in beef top round roasts reduces the development of WOF. Holding roasts at serving temperatures for extended periods of time does reduce WOF but results in a loss of tenderness and reduced moisture.

Introduction

Convenience has become an important factor in many meal planning decisions. Quickly prepared 'heat and serve' products are in demand. To stay competitive, the meat industry must continue to investigate methods to improve convenience. Precooking of beef roasts is a logical method, but has not been widely accepted by consumers, primarily due to off flavors that develop during storage. Precooking would also benefit restaurant and food service operations by reducing preparation time and increasing product utilization. The off flavors that develop are characterized by a rancid, stale, or metallic flavor produced during lipid oxidation. Tims and Watts (1958) first recognized these off flavors as warmed-over flavor (WOF). The 2-thiobarbituric acid test (TBA) has been effective in monitoring the development of WOF.

Antioxidants are very effective inhibitors of WOF. Compounds such as nitrite, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are common additives to meat and poultry products for the inhibition of lipid oxidation. These compounds, however, have a negative connotation among consumers, enhancing the production of natural antioxidants would be beneficial. With the introduction of legislation such as California's proposition 65 the possible necessity of using alternative antioxidants exists.

During heat processing the Maillard reaction forms products which have been shown to have antioxidant properties. The formation of these Maillard Reaction Products (MRP) is a result of an interaction between proteins and reducing sugars.

The formation of MRP is enhanced with the application of heat and with a decrease in moisture, conditions commonly found in food preparation. Dextrose, a reducing sugar and a common ingredient in processed meat products, is readily used in the formation of MRP.

This study was designed to determine the effect of dextrose level on the development of WOF and determine the influence of extended holding time on the development of WOF in beef top round roasts.

Material and Methods

Raw Material and Product Preparation

Six top round roasts were cooked per replication, consisting of two roasts per treatment. The top rounds were excised post rigor from USDA Choice carcasses of yield grades two or three and split medially. The roasts were removed from frozen storage (-20° C) where they had been for four months and allowed to thaw in a cooler at 4° C for 48 hours, removed from the vacuum packaging and trimmed of all external fat covering. The trimmed roasts, ranging in weight from 2.3 to 3.7 kilograms, were pumped to 110% of initial weight with one of three brine treatments of 0%, 1% or 2% dextrose by a multi-needle hand injector. Brines were formulated with deionized water to achieve a final product concentration of 0.2% sodium chloride, 0.3% sodium tripolyphosphate and either 0%, 1% or 2% dextrose. The roasts were covered with white butcher paper and stored overnight in the cooler (4° C) to equilibrate, then subjected to one hour of tumbling (Model VMR-35-526, Globus, South Hackensack, NJ.) under 90% vacuum using a cycle of 20 min on, 10 min off. The roasts were covered in white butcher paper and returned to the cooler for 8-10 hours until cooking.

Cooking and Sample Preparation

Prior to cooking all roasts were weighed. The roasts were cooked 3 per tray, on two stainless steel trays in a convection cook and hold oven (Jero Thermaflo Cook and Hold, Tulsa, OK.) at 121° C. Copper constantan thermal couples were placed in the geometric center of each roast and temperatures were recorded using a Omega OM-5000 data logger (Omega Engineering Inc., Stanford, CT). When the internal temperature of 54° C was reached, the roasts were reweighed and placed in a preheated holding oven (Jero Thermaflo Cook and Hold, Tulsa, OK.) set at 60° C. Product yields were determined as a percentage by dividing cooked weights by initial weights. After 2 hours of holding the roasts were weighed again and cut in half, with the posterior half being returned to the holding oven for an additional 4 hours to achieve the 6 hour holding treatment. The choice of holding times were used to mimic institutional cook and hold practices of cooking.

The roasts were cooled at room temperature (21° C) and then individual samples were taken from each roast for further analysis. The roasts were sampled starting at the cut end with the first 1.3 cm being discarded. A 1.91 cm slice was removed for Warner-Bratzler shear (WBS) determination, and five 0.65 cm slices were taken for TBA analysis. The slices were overwrapped with white butcher paper and stored in the cooler (4° C) for 8-10 hours. One set of slices from each roast was taken for TBA analysis for day 0, the remaining slices were placed individually on Styrofoam trays, overwrapped with polyvinylchloride (PVC) film, and placed on a rack in the cooler (4° C) to be sampled daily for a one week period. The WBS slices were vacuum packaged and placed in the cooler prior to analysis.

TBA

The 2-Thiobarbituric acid analysis was performed to monitor thiobarbituric acid reactive substances (TBARS) in the sample as a result of lipid oxidation. The distillation method of Tarladgis et al. (1960) was used modified with the addition of EDTA and Propyl Galate at the grinding stage as suggested by Rhee (1978), and with the use of filter paper (Whatman no.4) to purify the distillate. Duplicate samples were taken from each slice of the roasts. Absorbance was measured by spectrophotometer (Du 7500 Beckman Instruments Inc., Fullerton, CA) at 538nm.

Warner-Bratzler Analysis

Eight to ten cores (1.27 cm diameter) were taken from each of the 1.91 cm thick slices. Warner-Bratzler shear analysis was conducted by attachment to the Instron Universal Testing Machine (model #4502, Instron, Canton, Mass). A 1 kN load cell detected the force required to shear through the sample core as the crosshead moved at 50 mm/min. The peak force (N) was recorded by an IBM PS2 (Model 55 SX) using software provided by Instron Corporation and analyzed as an objective measurement for tenderness.

Proximate Analysis

Percentage moisture was determined by drying oven method, fat was determined according to the Modified Soxhlet Extraction procedures, and protein was determined by Kjeldahl digestion procedures according to AOAC methods (1984). Samples from each roast were pulverized with liquid nitrogen and used for proximate analysis procedures. Samples were analyzed in duplicate.

Statistical Analysis

Data were analyzed as a split block with dextrose level (0%,1% and 2%) as main block and holding time (2 and 6 hour) as split block, replicated 3 times (Steel and Torrie 1980). Means were separated and analyzed by using the Fisher protected LSD (Statistical Analysis System (SAS) 1988). All significant levels were $P< 0.05$.

Results and Discussion

TBA

The roasts with added dextrose showed a significant reduction in the progression of WOF (figure 3.1) which is in agreement with studies by Goll (1988). Figure 3.1 shows the results of the dextrose treatments on the TBA values over the 5 day storage period. All treatments follow the same general pattern, however, the 1% and 2% dextrose treatment significantly impeded the progress of WOF over that of the control, with the 2% dextrose level having a slight advantage over the 1% treatment. This is beneficial to the food service branch of the industry trying to prolong the flavor quality of their products. There was a significant difference between the TBA values of the different holding times (Figure 3.2), with the 6 hour holding time displaying a greater inhibitory effect. This could be due to the increased time in the oven producing a greater amount of antioxidant compounds and/or due to the extra loss of moisture causing a concentration of the antioxidant compounds.

Proximate analysis

Table 3.1 contains the results of the proximate analysis. The 6 hour holding time showed a significant loss of moisture over that of the 2 hour. While this is not a surprise due to the extra time in the oven, it will decrease the yield and will significantly decrease tenderness of the product (Figure 3.3). So there is a trade off, with the increased holding time comes the advantage of increased WOF inhibition, but also the detrimental effects of loss of yield and tenderness.

There was a significant effect of dextrose level in the protein concentration of the product. The 2% dextrose level was significantly lower than both the 0% and 1% treatments. This is due to the trend for dextrose to increase the moisture content. The added moisture causes a supplementary decrease in protein and fat as is the case with the decreasing trends in protein and fat in the dextrose treatments and the reverse trend for increasing protein and fat due to the loss of moisture between the holding times.

Warner-Bratzler shear

There was a significant difference in WBS values for the holding times. As expected due to the increased loss of moisture the 6 hour holding time has a significantly higher shear force value (Figure 3.3). This difference in holding time is substantiated by an experiment by Martens et al. (1982) in which shorter holding times were used, yet significant reductions in tenderness were incurred with increased holding time. There was no significant difference in shear values due to dextrose level.

Yield

The product yields are represented in figure 3.4. There is a significant dextrose by holding time effect. The 0% dextrose treatment shows a decrease in product yield from 2 to 6 hours holding but it is not significant. The 1% and 2% dextrose treatments, however, show a significantly higher product yield for the 2 hour holding time over that of the 6 hour treatment. The 1% and 2% dextrose treatments also have a significantly higher product yield at the 2 hour holding time than that of the 0% dextrose treatment. The decrease in yields is a function of the extra evaporation loss and drip loss (Schoman and Ball, 1961). The studies by Martens et al. (1982) showed an increased cooking loss associated with increased holding time. The addition of dextrose to the product increases the yield, with the 2% treatment having significantly higher yields than that of the control. Therefore, the addition of dextrose to beef top round roast inhibits WOF and improves yields.

Conclusion

The results show that the 1% and 2% dextrose treatments were effective in inhibiting WOF, and that the extended holding time also inhibited WOF development. The proximate analysis showed a trend for increasing dextrose level to increase moisture content. The addition of dextrose also increased the yield of the final product.

This study suggests that dextrose can be used as an ingredient in beef roasts as an inhibitor of warmed over flavor. Consumers are more likely to accept dextrose as an ingredient in meat products compared to chemical additives. This may increase acceptance of more convenient, precooked beef roasts. The addition of dextrose also increases product yields without effecting the tenderness of the product.

Extended holding times, such as 6 hours, adds an additional WOF inhibition, but it also results in the loss of yield and tenderness. However, if a product must be held for longer periods of time at serving temperature one deleterious aspect that need not cause increased concern is WOF.

TABLE 3.1

PROXIMATE ANALYSIS RESULTS FOR TOP ROUND ROASTS ANALYZED BY DEXTROSE LEVEL OR HOLDING TIME

	Dextrose Level				Hold Time		
	0%	1%	2%	se[a]	2 hr	6 hr	se[a]
Protein %	28.7[b]	28.4[b]	27.4[c]	.3	27.9[b]	28.5[b]	.2
Fat %	3.3[b]	2.8[b]	2.5[b]	.3	2.6[b]	3.1[b]	.3
Moisture %	66.0[b]	66.5[b]	67.2[b]	.4	67.2[b]	65.9[c]	.3

[a]se = Standard error

[bc] means with like superscripts within main effect are not significantly different (P>.05)

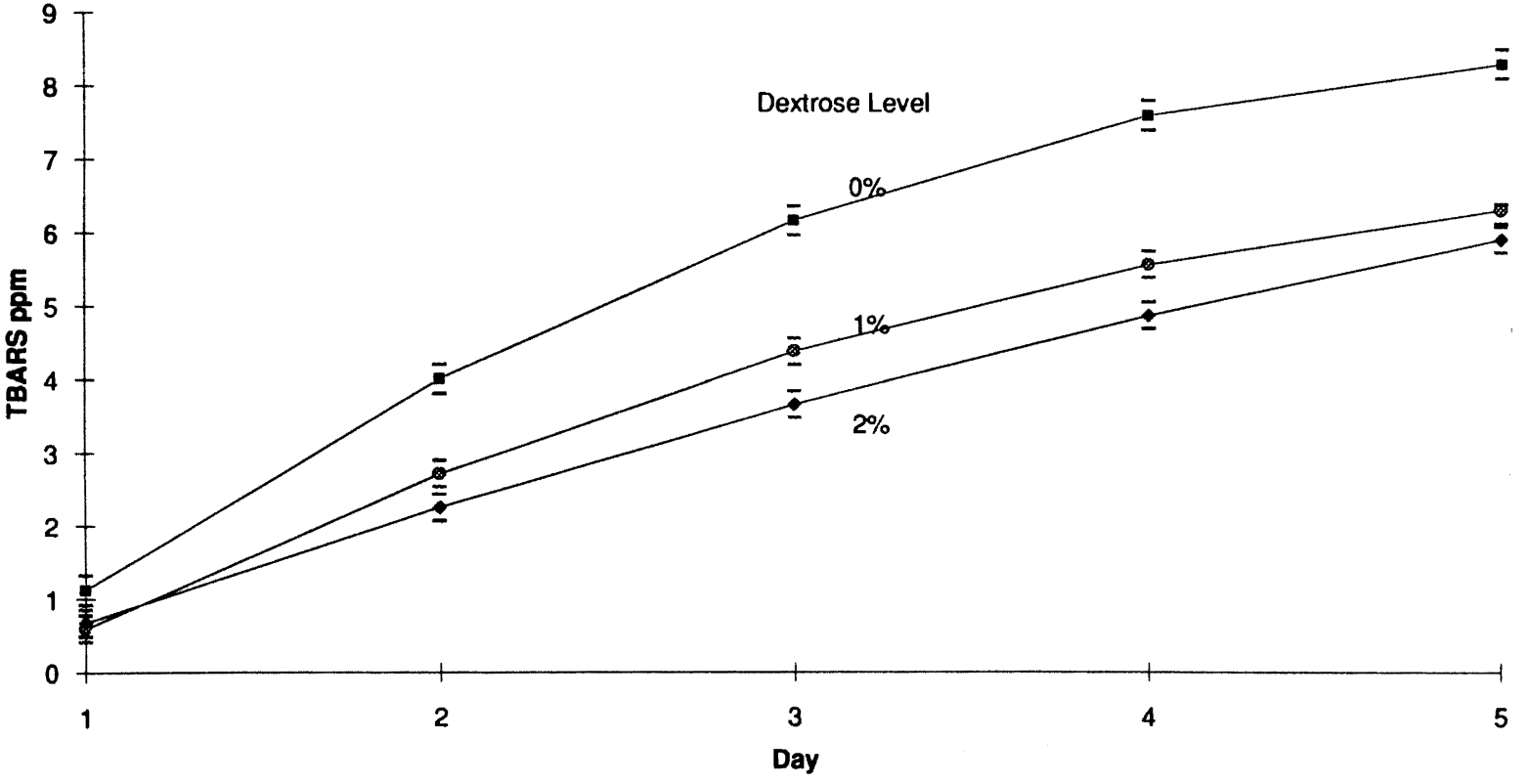
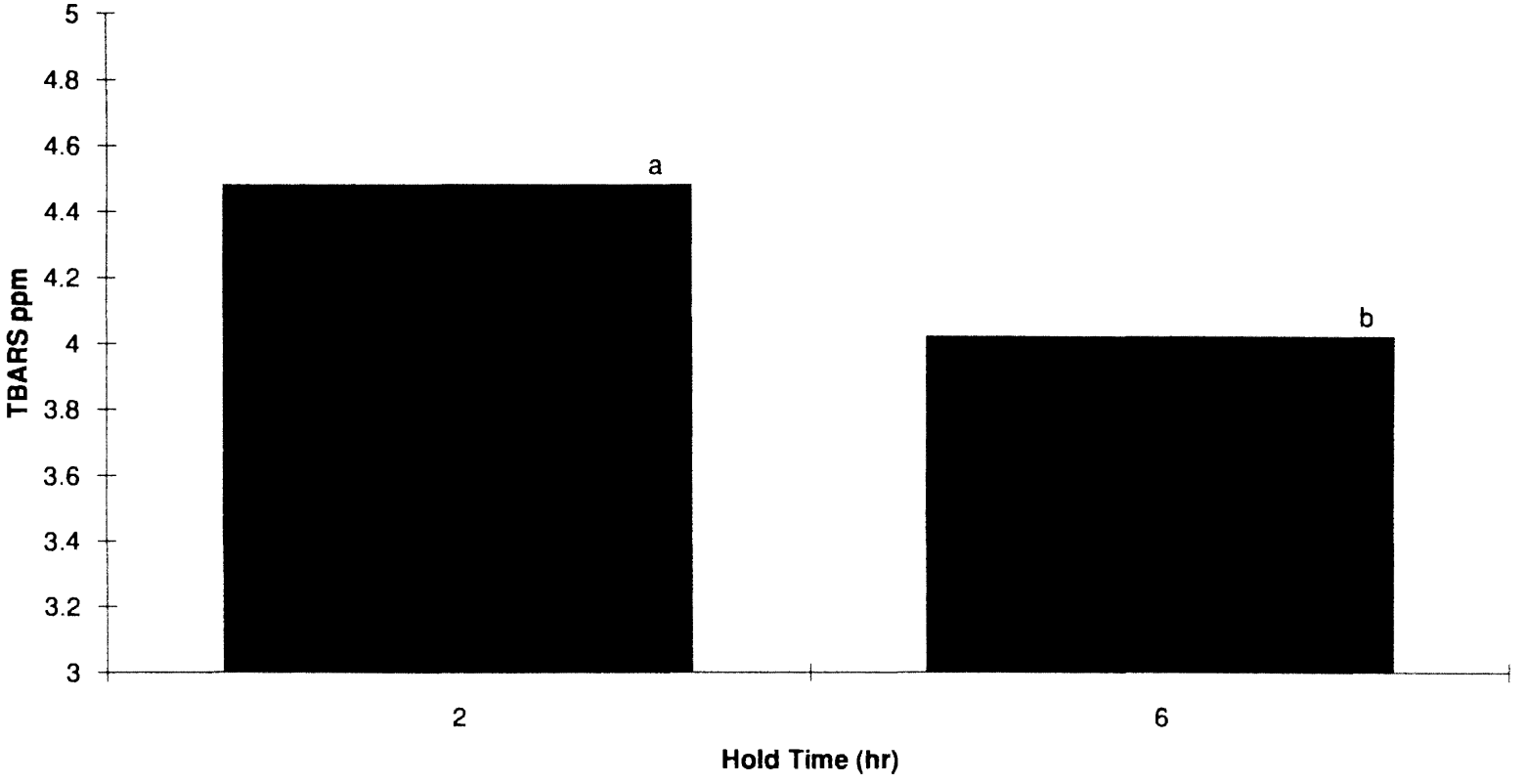
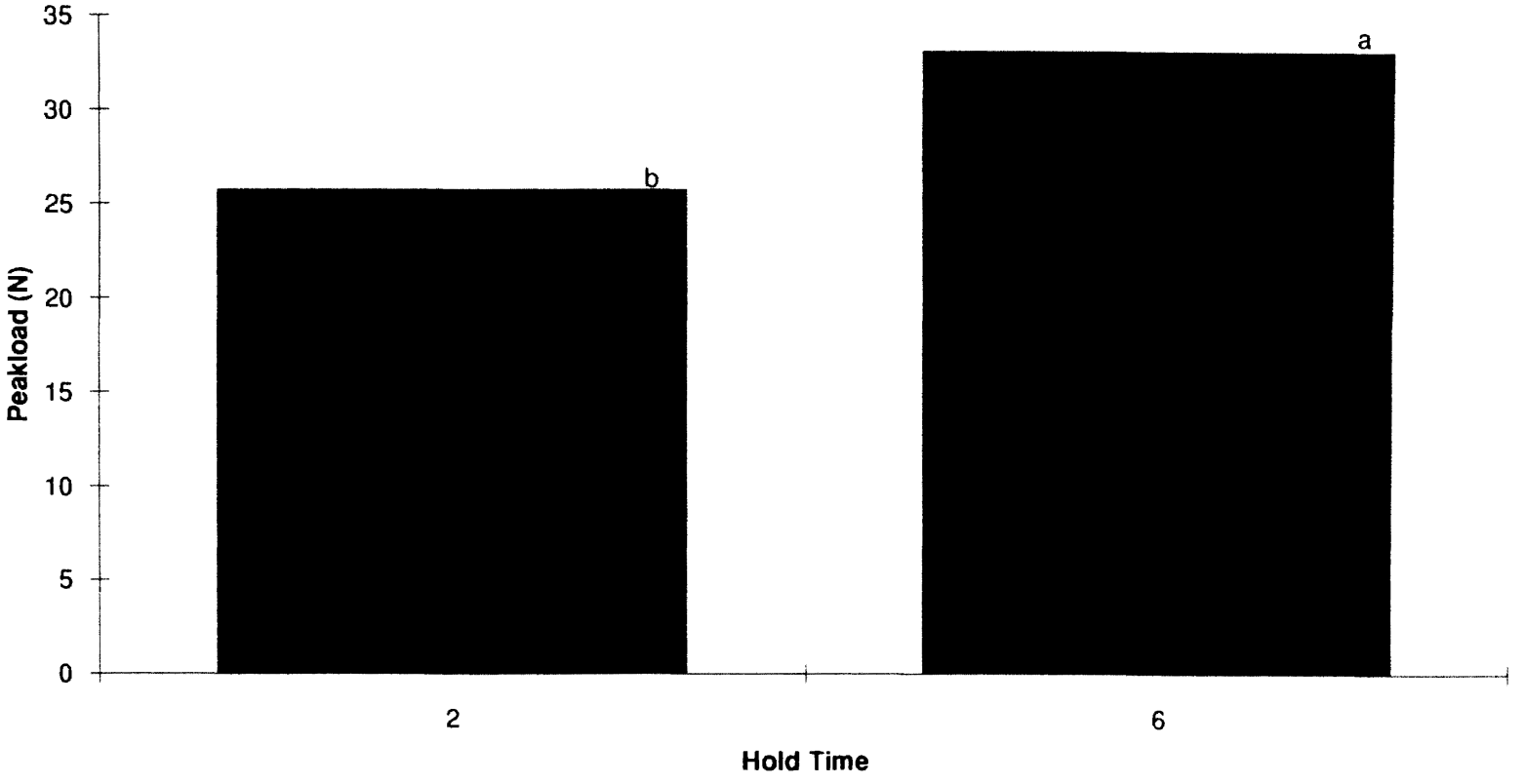


Figure 3.1 Effect of Storage Time on 2-Thiobarbituric Acid Results of Top Round Roasts Injected with Different Dextrose Levels.



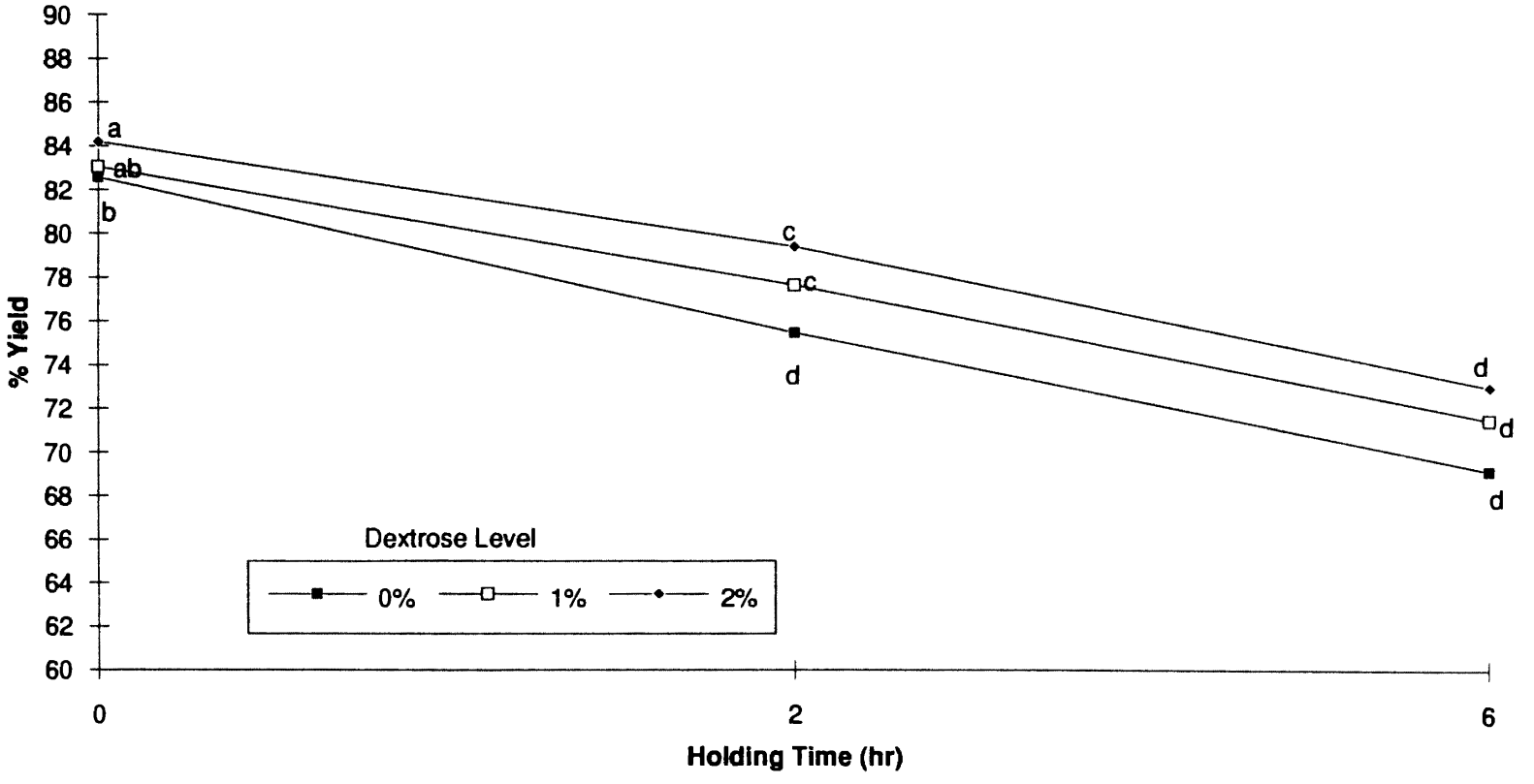
[ab] Means with like superscripts are not significantly different

Figure 3.2 Effect of Holding Time on the 2-Thiobarbituric Acid Results of Top Round Roasts.



[ab] Means with like superscripts are not significantly different

Figure 3.3 Effect of Holding Time on the Peak Force Required to Shear Throung Core Sample from Top Round Roasts.



[ab] Means with like superscripts are not significantly different

Figure 3.4 Effect of Holding Time on the Cooked Yields from Top Round Roasts Injected with Different Dextrose Levels.

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CHAPTER IV

DEXTROSE LEVEL AND COOKING TEMPERATURE AFFECTS ON WARMED-OVER FLAVOR OF WHOLE AND RESTRUCTURED BEEF TOP ROUND ROASTS

Abstract

Due to consumer demand for convenient products, precooking of beef roast would be a logical method of increasing the convenience of meat products. One hurdle to overcome in the production of such a product is the development of warmed over flavor (WOF). It was the intent of this study to determine the influence of added dextrose on the inhibition of WOF in both whole muscle and restructured products, and the influence of low and high cooking temperatures on the development of WOF. Three brines were formulated with deionized water and injected into top round roasts to achieve a final concentration of 0.2% sodium chloride, 0.3% phosphate and either 0%, 1% or 2% dextrose. Restructured roasts were formulated to contain the same treatment concentrations. Roasts were cooked to 60° C internal temperature in ovens set at a low temperature of 121° C or a high temperature of 190.5° C. 2-Thiobarbituric acid (TBA) analysis showed a significant reduction in WOF development with the addition of dextrose treatments for the high cooking temperature. Sensory panel analysis showed the 2% dextrose treatment to significantly lower the detection of WOF. Kramer shear force increased with the higher cooking temperature. Proximate analysis showed a significant decrease in

moisture concentration for the higher cooking temperature, which resulted in significantly lower yields. The inclusion of dextrose to whole muscle roasts can be useful as an inhibitor of WOF, as well as decreasing the perception of WOF by consumers.

Introduction

Due to the ever increasing desire and demand for convenient meals in society today, it is much more common for 'heat and serve' products to be available, ranging from 'T.V. dinners' to airline food service. There is a constant need for new products and ideas to help supply the convenience demand. Precooked products, especially meat products, have had hurdles to overcome on the journey to popularity. One such hurdle, warmed-over flavor (WOF), is described as the metallic, rancid or stale flavor associated with oxidized refrigerated cooked meats. First described by Tims and Watts (1958), the term has been expanded to include oxidized fresh meat products such as ground meat, which are highly susceptible to lipid oxidation.

There are antioxidants which are very effective inhibitors of WOF. Compounds such as nitrite, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are common additives to all kinds of food products to preserve flavor. However, along with the demand for convenience, consumers are asking for less preservatives and less additives in food, for a label with more natural ingredients. With the legislation like California's proposition 65, chemical additives like BHA are being removed from food products and replaced with alternatives that are less controversial.

During heat processing the Maillard reaction forms products which have been shown to have antioxidant properties. The formation of Maillard Reaction Products

(MRP) is a result of an interaction between proteins and reducing sugars. The formation of MRP is enhanced with the application of heat and with a decrease in moisture, conditions commonly found in food preparation and processing. Dextrose, a reducing sugar and a common ingredient in processed meat products, is readily used in the formation of MRP.

This study was designed to determine the effect of dextrose on the development of WOF in whole and restructured top round beef roasts, and to determine the influence of cooking temperature on the development of WOF. To study the applicability of using dextrose to increase the Maillard reaction and its antioxidant effects as an alternative to BHA in whole muscle and restructuring processes.

Material and Methods

Raw Material and Product Preparation

Whole Muscle Roasts Six top round roasts were cooked per replication, consisting of two roasts per treatment. The top rounds were excised post rigor from choice carcasses of yield grades two and three and split medially. The roasts were removed from frozen storage (-20° C) where they had been stored for 9 months and allowed to thaw in a cooler at 4° C for 48 hours, removed from the vacuum packaging and trimmed of all external fat covering. The trimmed roasts, ranging in weight from 2.3 to 3.7 kilograms, were pumped by a multi-needle hand injector to 110% of initial weight with one of the three brine treatments of 0%, 1% or 2% dextrose. The brines were formulated with deionized water to achieve a final product concentration of 0.2% sodium chloride 0.3% sodium tripolyphosphate and 0%, 1% or 2% dextrose.

The roasts were covered with white butcher paper and stored 8-10 hours in the cooler (4°C), then subjected to one hour of tumbling (Model VMR-35-526, Globus, South Hackensack, NJ.) under 90% vacuum using a cycle of 20 minutes on, 10 minutes off. The roasts were covered in white butcher paper and returned to the cooler for 8-10 hours until cooking.

Restructured Roasts Eight top round roasts were used per replication. The top rounds were excised post rigor from choice carcasses of yield grades two and three and split medially. The roasts were removed from frozen storage (-20° C) where they had been stored for 11 months and allowed to thaw in a cooler at 4° C for 48 hours, removed from the vacuum packaging and trimmed of all external fat covering. The fat was cut into strips of approximately 3.8 cm in width, vacuum packaged (Multivac, KOCH Supplies, Kansas City, MO.) in pouches (FreshPak 500™, KOCH Supplies, Kansas City, MO.) refrozen (-20° C). The lean tissue was cut manually into approximately 227 gm chunks, to facilitate grinding and to remove all possible seam fat. The meat was then ground through a 1.27 cm grinding plate (Biro Mfg. Co, Marblehead, OH), weighed, immediately vacuum packaged (Multivac, KOCH Supplies, Kansas City, MO.) in pouches (FreshPak 500™, KOCH Supplies, Kansas City, MO.) and placed in the cooler (4° C) for 8-10 hours until production. A sample of the lean was taken prior to vacuum packaging for use in the Modified Babcock test.

After freezing the fat was removed from the freezer and reduced to fine flakes with a comitrol (model 3600, Urschel Laboratories Inc. Valparaiso, IN) using the 0.4 cm head to provide for a fine dispersion of the fat in the final product. A sample of the fat was taken for use in the Modified Babcock test and the fat was temporarily placed in the freezer while the analysis was run. The Modified Babcock test was conducted to determine the fat content of both the fat and lean portion for use in roast

formulation. The roasts were formulated to contain 8% fat , 0.2% sodium chloride, 0.3% phosphate and either 0%, 1% or 2% dextrose.

The preformulated amounts of lean, fat and dry ingredients were mixed together in a Leland ribbon-paddle mixer (Model L100DA, Detroit Mfg., Detroit, MI.) for a total of 12 minutes, for each of the three dextrose treatments. The mixture was stuffed through a Vemag vacuum stuffer (model 500 distributed by Robert Reiser Co Inc. Canton, Mass) into cellulose casings (7R, Viskase, Chicago, IL.), clipped and placed in the freezer for 48 hours. Once frozen the roasts were removed from the freezer and tempered in the 4° C cooler for 8-10 hours, the casings was removed and the roasts were then pressed using a Bettcher Press (model 70, Birmingham, OH). The roasts were vacuum packaged (Multivac, KOCH Supplies, Kansas City, MO.) in pouches (FreshPak 500™, KOCH Supplies, Kansas City, MO.) and placed back in the freezer, frozen, and tempered as before, then cooked.

Cooking and Sample Preparation

Prior to cooking weights were taken on all roasts. The roasts were cooked three per shelf in the middle of two identical Roper gas ovens (model # FGS397X, Denver, CO.) at one of two different environmental temperatures of 121°C or 190.5°C. A copper constantan thermal couple was placed in the geometric center of each roast and temperatures were recorded using an Omega OM-5000 data logger (Omega Engineering Inc., Stanford, CT). When the internal temperature of 60°C was achieved, the roasts were removed and allowed to cool at room temperature (21° C). Cooking rate was determined by dividing the time it required to bring a roast to the endpoint internal temperature of 60° C by the weight of the roast. Once cooled individual samples were taken from each roast for further analysis. The first 1.3 cm were discarded and then a 1.91 cm slice was removed for shear and proximate

analysis, Warner-Bratzler shear for the whole muscle roasts and Kramer shear for the restructured. Then ten 0.65 cm slices were made, five for TBA and five for Sensory panel. All slices were vacuum packaged (Multivac, KOCH Supplies, Kansas City, MO.) in small pouches (6.00 by 10.00 MIL 3, KOCH Supplies, Kansas City, MO.) boxed and placed in the cooler (4°C) awaiting analysis. After 24 hours the first set of slices were analyzed as week 1 and subsequent analyses being run every week for five consecutive weeks. The TBA analysis lasted the full five weeks, however, due to high microbial counts the sensory panel was conducted for four weeks on the whole muscle product and three weeks on the restructured roasts.

TBA

The 2-Thiobarbituric acid analysis was performed to monitor thiobarbituric acid reactive substances (TBARS). The distillation method of Tarladgis et al. (1960) was used modified with the addition of EDTA and Propyl Galate at the grinding stage as suggested by Rhee (1978), and with the use of filter paper (Whatman no.4) to purify the distillate. Duplicate samples were run from each slice of the roasts. Absorbance was measured by spectrophotometer (Du 7500 Beckman Instruments Inc., Fullerton, CA.) at 538nm.

Instron Shear Measurements

Warner-Bratzler Analysis Eight to ten 1.27 cm diameter cores were taken from each of the 1.91 cm thick slice of the whole muscle roasts. Warner-Bratzler shear analysis was conducted by attachment to the Instron Universal Testing Machine (model #4502, Instron, Canton, Mass). A 1 kN load cell detected the force required to shear through the sample core as the crosshead moved at 50 mm/min. The peak force (N) was

recorded by an IBM PS2 (Model 55 SX) using software provided by Instron Corporation and analyzed as an objective measurement for tenderness.

Kramer Shear A 4 cm^2 section was removed from each 1.91 cm slice of the restructured roasts and peak shear force was recorded as it was sheared by a Kramer shear attachment to the Instron Universal Testing Machine model #4502 (Instron, Canton, Mass). A 1 kN load cell detected the force required to shear through the sample as the crosshead moved at 50 mm/min. The peak force (N) was recorded by an IBM PS2 (Model 55 SX) using software provided by Instron Corporation and analyzed as an objective measurement for tenderness in relation to the cohesive bind on the restructured roasts.

Proximate Analysis

Percentage moisture was determined by drying oven method, fat was determined according to the Modified Soxhlet Extraction procedures, and protein was determined by Kjeldahl digestion procedures according to (AOAC, 1984). Samples from each roast were pulverized with liquid nitrogen and used for proximate analysis procedures, samples were analyzed in duplicate. Product yields were determined as a percentage by dividing cooked weights by initial weights.

Sensory Panel

A six to ten member trained taste panel , made up of graduate students, staff and professors, evaluated the samples each week for tenderness, juiciness, connective tissue, saltiness, beef flavor intensity, off flavor and description of off flavor. Panelists were selected and trained according to the procedures outlined by Cross et

al. (1978). Training consisted of differentiating between freshly cooked patties and different degrees of WOF in beef patties previously cooked, stored for different periods of time and reheated for presentation. Training in differentiating texture, juiciness, connective tissue and beef flavor was done with the use of various cuts beef with differing quality and yield grades.

Samples of the roasts were scored on an eight point scale for tenderness, juiciness, connective tissue, flavor intensity and off flavor (1= extremely tough, dry, abundant, extremely bland, and abundant, 8= extremely tender, juicy, none, extremely intense, and none). Saltiness was scored on a six point scale (1= extremely salty, 6= none). Descriptions of off flavors were provided for use: sweet, sour, acidic, metallic, cardboard, serumy, grassy, buttery, painty (Love. 1988).

The samples for taste panel were cut into 1.27 cm^2 pieces, placed in glass yogurt maker glassware (model GM-5W, Salton/Maxim Housewares group, Mt. Prospect, IL), heated in a microwave under 70% power for one minute, capped and placed in the yogurt maker holder. The order of presentation was randomized to reduce position effect. Each panelist was given a yogurt maker containing six samples for evaluation. The panelists were seated in individual cubicles to minimize distraction and assure independent scoring. Red lights overhead were used to minimize color influence and each panelist was provided with distilled water to clear the mouth between samples so residual flavors did not interfere with scoring.

Statistical Analysis

Data were analyzed as a split block with dextrose level as main block and cooking temperature as split block and replicated 3 times for each style of roast (Steel

and Torrie 1980). Means were separated and analyzed by using the Fisher protected LSD (Statistical Analysis System (SAS) 1988). All significant levels were $P< 0.05$.

Results and Discussion

TBA

The results from the whole muscle roast TBA test showed that there was a significant dextrose by temperature effect (Figure 4.1). The amount of oxidation for the 0% dextrose level is significantly increased for the higher cooking temperature. This is in agreement with Huang and Greene (1978) and Arganosa et al. (1991) who found that faster rates of cooking at higher temperatures produced higher TBA numbers after storage than slower rates at lower temperatures, until internal temperatures of 80° C or greater are reached. The 1% dextrose treatment did not show any significant difference between the two cooking temperatures. The 2% treatment does show a significant difference between the two cooking temperatures, with the lower temperature having the higher oxidation. The dextrose effects observed in Study I are not apparent here. This could be due to the fact that the roasts in the first study were held for a minimum of 2 hours and that the holding time caused the dextrose to be more effective. Or it is possible that the difference between the types of heating equipment used in the two studies, with an electric oven in Study I and gas ovens in Study II, could be causing some observed differences with the 2% dextrose level. The data suggest that the addition of dextrose as an inhibitor of WOF is more applicable at higher cooking temperatures or faster rates of heating.

The TBA data from the restructured roasts proved not to be significant. Due to the nature of restructuring procedures, specifically the comminuting stage, the meat was exposed to oxygen early in the process without antioxidant protection until

cooking. This oxidation of the restructured roasts was more advanced than the whole muscle roasts from the start of TBA analysis. It would appear that this technique is not practical for restructured products, due to the delay in time for the antioxidant protection to occur. The addition of preformed MRP at the time of comminuting would more appropriate, which is in agreement with findings by Lingnert and Lundgren (1980) in which it was shown that preformed MRP were effective in preventing WOF in sausage products, and that it was important to apply the lipid oxidation protection as early as possible in the manufacture of the product.

Sensory Panel

Results from the whole muscle taste panel results showed off flavor to be the only significant component. The effect of dextrose level by week (Figure 4.2) showed a decline in taste panel scores which would correspond to an increase in off flavor on the 8 point scale used. The data also shows the 2% dextrose level to have the most off flavor of the treatments. Upon analysis of the description of off flavor (data not shown) the taste panel described the 1% treatment as 'sweet' 17% of the time and the 2% treatment as 'sweet' 46% of the time. It is important to note that more than one description of off flavor could be used to describe an individual sample. Therefore, while the 2% treatment shows increasing off flavor (Figure 4.2) the off flavor being detected could be sweetness.

When description of off flavor is analyzed (Figure 4.3) for 'WOF' descriptions both the 1% and 2% dextrose treatments are significantly lower in WOF detection by taste panelists. The addition of dextrose proves to inhibit WOF to some extent and it decreases the detection of WOF by panelists, as it would consumers. Data by White et al. (1988) indicates that consumers, unlike trained taste panelists, can not detect the difference between samples with TBA 6.3 or lower and freshly prepared products.

The taste panel data showed quite a few trends that did not prove to be significant, but are worth mentioning (data not shown). The addition of the dextrose tended to increase the perception of tenderness, juiciness and beef flavor intensity. Interesting to note, the addition of dextrose tended to decrease the perception of connective tissue, which is probably more closely connected to the perceived increases in tenderness and juiciness. The increase in temperature also tended to decrease the perception of both tenderness and juiciness. A study by Martens et al. (1982) also showed a decrease in juiciness and tenderness as cooking temperature increased.

Here again the restructured data proved not to be significant. Due to the same reasons as for the TBA results. The effects of dextrose were unable to overcome the heightened initial oxidation level.

Proximate analysis

Data in tables 4.1 and 4.2 provide information concerning the proximate analysis of the whole muscle and restructured roasts respectively. The only significant difference in the analysis of the whole muscle roasts occurred between the cooking temperatures for the moisture content. This would be expected for the harsher cooking environment to produce a product with decreased moisture content.

With dextrose adding increased moisture holding ability there were trends in the data for moisture content to increase. This caused a supplementary trend for fat and protein content to decrease. The addition of the dextrose to the roasts would also tend to dilute the protein and fat contents. These trends were evident in the data for both whole muscle and restructured roasts.

The proximate analysis for the restructured roasts displayed a significant difference in the protein and moisture contents due to temperature. The higher

temperature caused a decrease in moisture which lead to a corresponding increase in protein.

Warner-Bratzler shear analysis

The WBS analysis displayed a trend for the peak force to decrease with increasing dextrose levels (Figure 4.4). There was also a trend for peak force to increase with the higher cooking temperature (Figure 4.5). Studies by Davey and Gilbert (1974), Locker and Daines (1974) and Bouton et al. (1981) noted an increase in WBS force with increased cooking temperature. These effects would be due to the moisture content of the roasts. Dextrose tends to add moisture, thus lowering the peak force values. The higher temperature cooking treatment has proven to significantly lower moisture content (Schoman and Ball, 1961., Martens et al., 1982).

Kramer shear analysis

The Kramer shear analysis on the restructured roasts displayed a significant increase in peak force with the higher cooking temperature (Figure 4.6). This is again due to the moisture content. A corresponding trend is shown with increasing dextrose levels to decreasing peak force values (Figure 4.7).

Cooking Rate

The roasts started at 4° C internal temperature. Significant differences were found in cooking rate between the cooking temperatures of both the whole muscle (Figure 4.8) and the restructured roasts (Figure 4.10), with the higher temperature requiring significantly less time. Studies by Schoman and Ball (1961) showed that cooking time decreased as cooking temperature increased. However, there was also a

significant difference in the cooking rate by temperature between the whole muscle and restructured roast. The restructured roast were smaller and weighed less, yet required almost twice the cooking rate. Bramblett and Vail (1964) noted in their experiments that smaller muscles required a longer time per pound than do larger muscles.

The restructured roasts had a significant effect of dextrose on the cooking rate (Figure 4.9). The 2% dextrose treatment had a significantly faster cooking rate than the 0% level. This could be due to the increased moisture associated with the increased dextrose level and a possible increased heat conductivity due to the dextrose.

Yield

The cooking yield for both whole muscle and restructured roasts is represented in figure 4.11, both roasts had the same cooked yields. There is a significant difference between the cooking temperatures, with the lower temperature having the higher yield. This effect is again related to the gentler treatment at the lower temperature and the effect on moisture content. Schoman and Ball (1961) noted in their study on top round roasts that higher oven temperatures caused a higher evaporation loss thus lowering the percent yield. There was also a trend in the whole muscle roasts for the addition of dextrose to increase the cooked yield of the product. This trend was present in the restructured roasts to a smaller extent (data not shown).

Conclusions

The 1% dextrose treatment showed a significant inhibition with the higher cooking temperature. Sensory Panel analysis showed 1% and 2% dextrose treatments

to significantly inhibit the detection of WOF by taste panelists, while at the same time tending to increase the perception of tenderness, juiciness and beef flavor. There was also a trend for increasing dextrose treatments to decrease WBS peak force.

The results from this study suggest that the addition of dextrose to whole muscle roasts can be useful as an inhibitor of WOF. Dextrose addition is more effective in higher cooking temperatures. The addition of dextrose will mask the perception of WOF to the consumer and at the same time tend to increase the perception of desirable qualities such as tenderness and juiciness. The addition of dextrose tends to increase yields which is an important factor when evaluating a product or design for production.

The effect of the cooking temperatures are more difficult to separate out. The lower cooking temperature is gentler to the product with more desirable results in the shear analysis and product yields. At the lower cooking temperature dextrose treatment does not seem to have a profound effect. However, the link with temperature and dextrose level on TBA analysis and WOF could be an area for future investigation.

The obvious conclusion from this study is that this particular use of MRP is not suited for use in restructured products.

The oven dry heat method used in this study are not the most ideal for the inhibition of WOF. However, if the positive effects of dextrose can be seen under less than ideal conditions than they could by better under more desirable cooking methods. The cooking method used by Mann et al. (1989) used airtight shrink bags around the roasts and to cook them in a heated water bath. This method would be more practical in industry for precooked products, with a reduced chance for oxidation and WOF. The positive aspects of this study could be easily transferred to such a cooking

method. The use of the different dextrose levels in such a cooking system is also another avenue for future investigation.

Before the application of a 2% dextrose level to such a product investigations should be made into the area of consumer acceptance of a possibly 'sweet' product, as it was defined by the taste panel at this level. This study shows the addition of dextrose to whole muscle roasts can be used as an effective inhibitor of WOF with positive effects on palatability.

TABLE 4.1

PROXIMATE ANALYSIS RESULTS FOR TOP WHOLE MUSCLE ROASTS ANALYZED BY DEXTROSE LEVEL OR COOKING TEMPERATURE

	Dextrose Level				Temperature		
	0%	1%	2%	se[a]	121° C	191° C	se[a]
Protein %	28.5[b]	27.8[b]	26.4[b]	.7	26.5[b]	28.6[b]	.6
Fat %	3.1[b]	3.2[b]	2.8[b]	.3	2.7[b]	3.3[b]	.3
Moisture %	67.1[b]	67.3[b]	67.8[b]	.7	68.8[b]	66.0[c]	.6

[a]se = Standard error

[bc] means with like superscripts within main effect are not significantly different (P>.05)

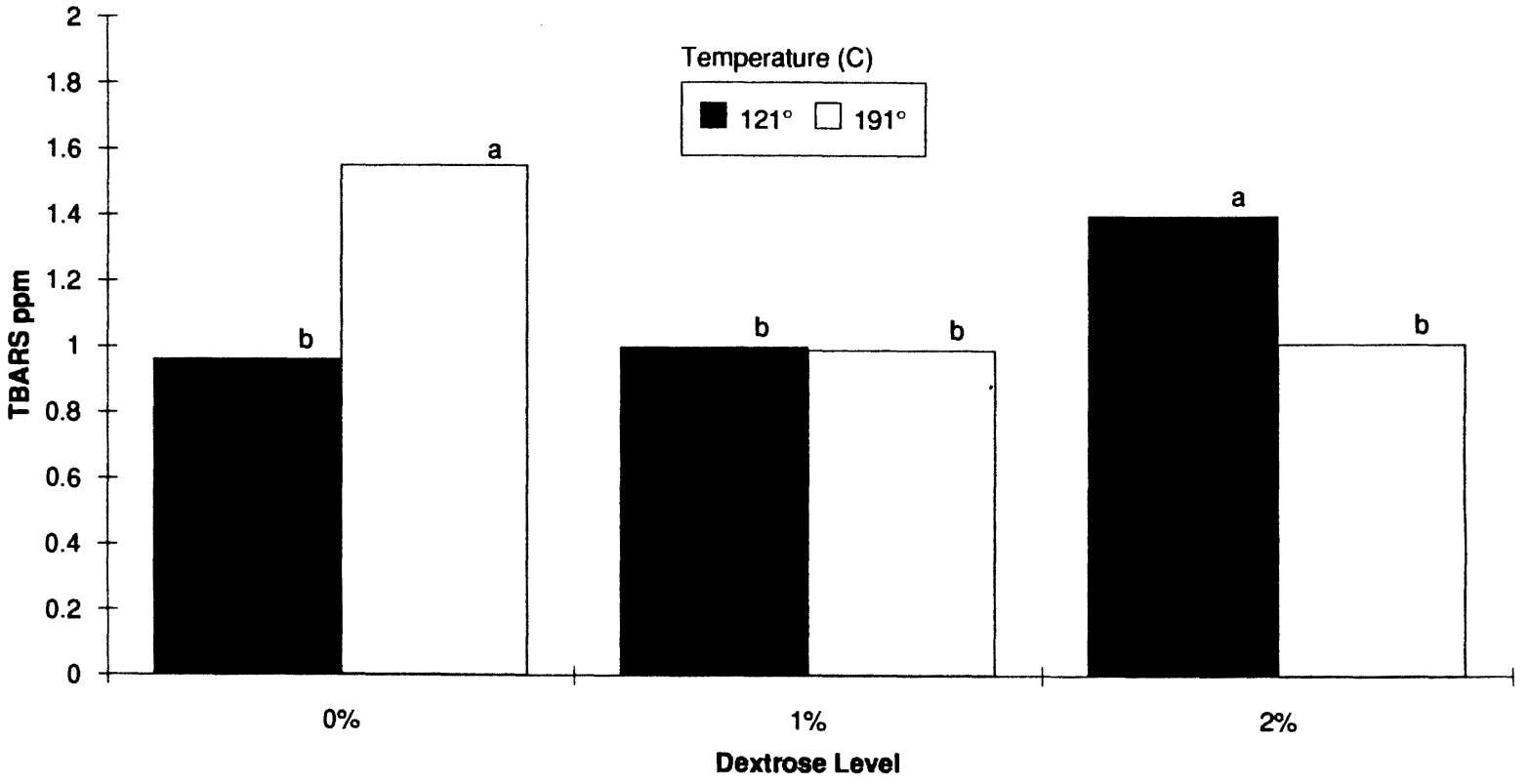
TABLE 4.2

PROXIMATE ANALYSIS RESULTS FOR TOP RESTRUCTURED ROASTS ANALYZED BY DEXTROSE LEVEL OR COOKING TEMPERATURE

	Dextrose Level				Temperature		
	0%	1%	2%	se[a]	121° C	191° C	se[a]
Protein %	31.3[b]	30.6[b]	30.3[b]	.5	28.9[c]	32.5[b]	.4
Fat %	6.6[b]	6.8[b]	6.8[b]	.5	6.6[b]	6.8[b]	.2
Moisture %	60.5[b]	61.0[b]	61.0[b]	.5	62.9[b]	58.9[c]	.4

[a]se = Standard error

[bc] means with like superscripts within main effect are not significantly different (P>.05)



ab Means with like superscripts are not significantly different

Figure 4.1 Effect of Dextrose Level on 2-Thiobarbituric Acid Results from Whole Muscle Roasts Cooked at Different Temperatures.

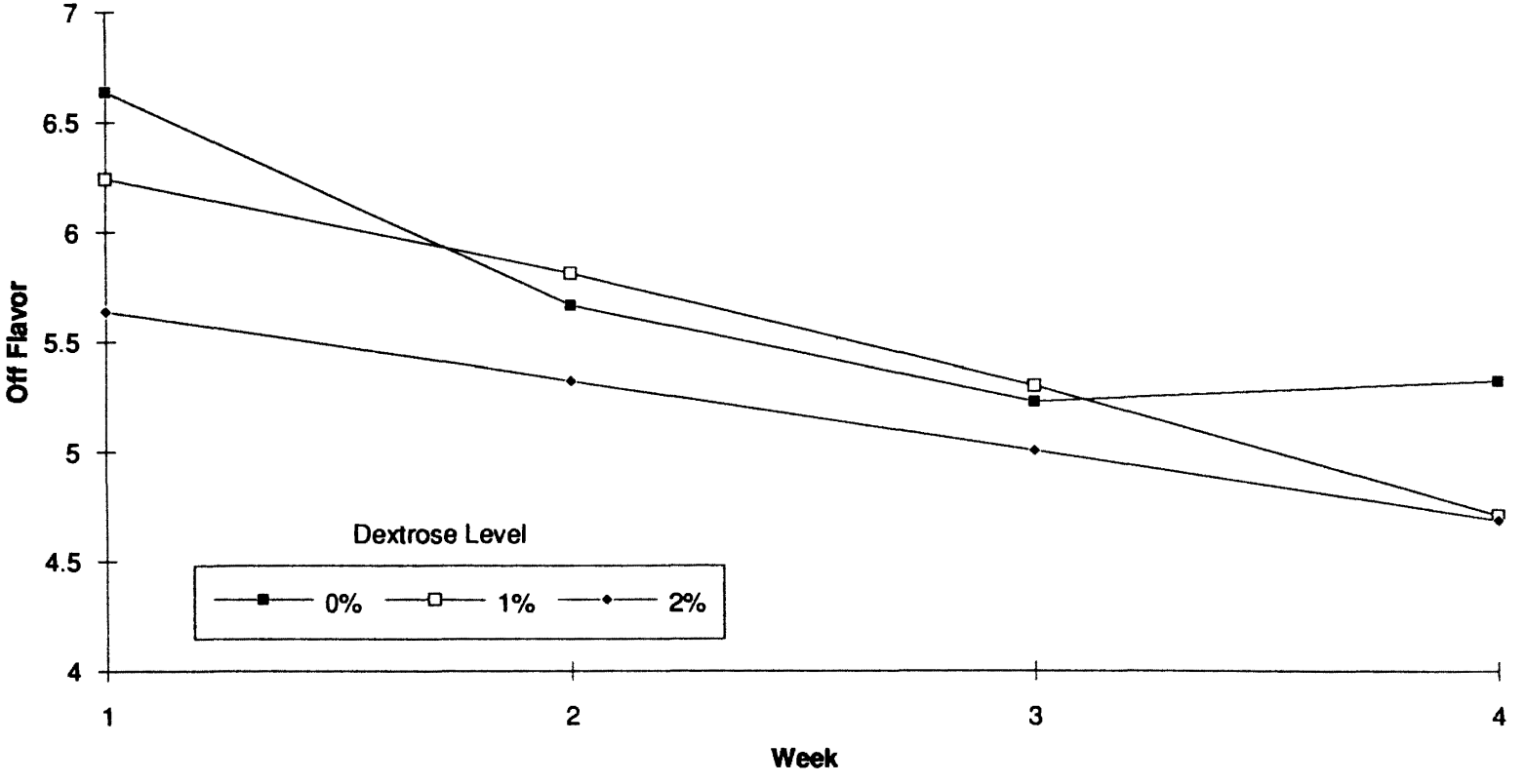


Figure 4.2 Taste Panel Off Flavor Scores of Whole Muscle Roasts Injected with Different Dextrose Levels and sampled over a 4 Week Period.

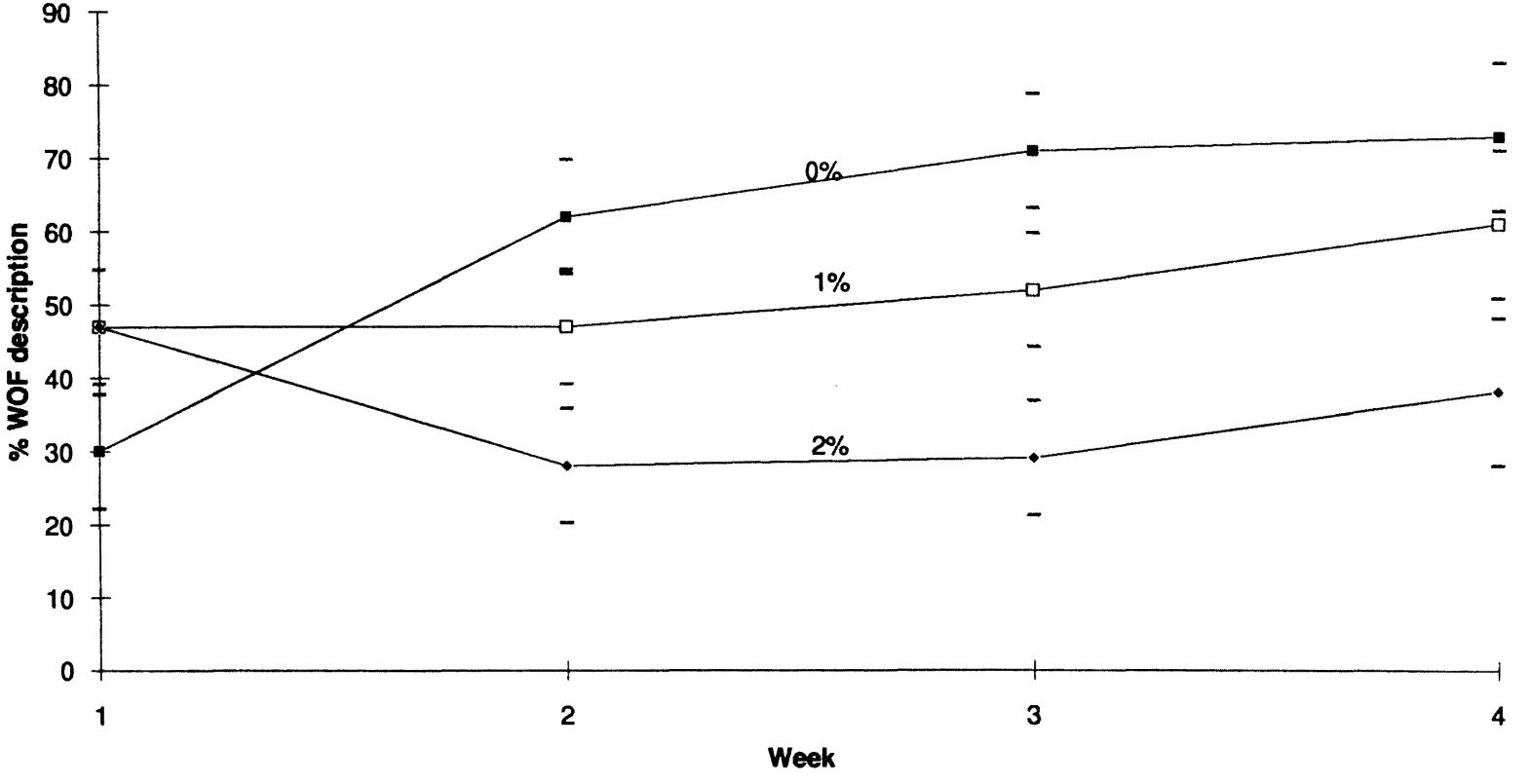


Figure 4.3 Effect of Dextrose Level on Whole Muscle Taste Panel Warmed-Over Flavor Description Percentage Sampled over a 4 Week Period.

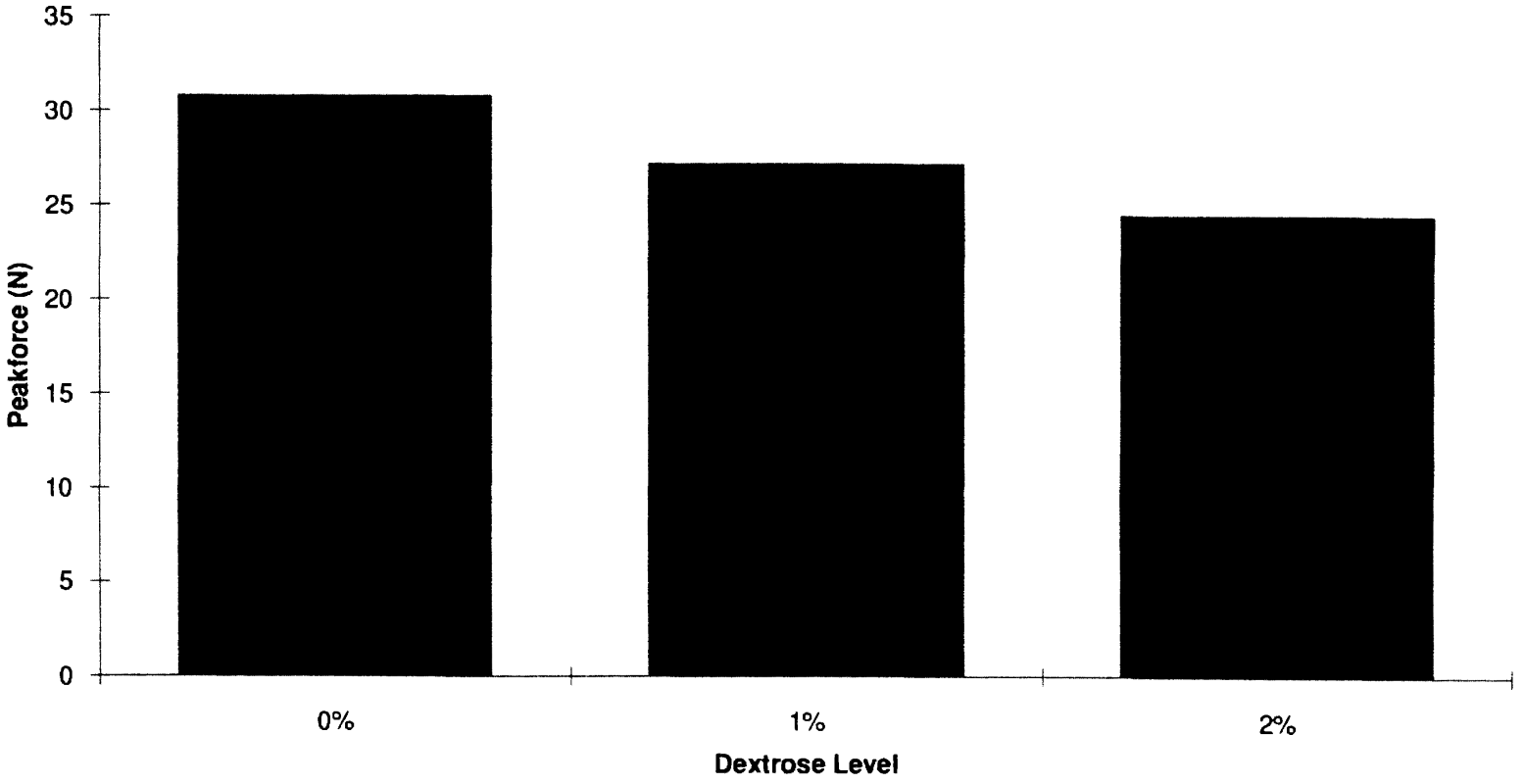


Figure 4.4 Effect of Dextrose Level on the Peak Force Required to Shear Through Core Samples from Whole Muscle Roasts.

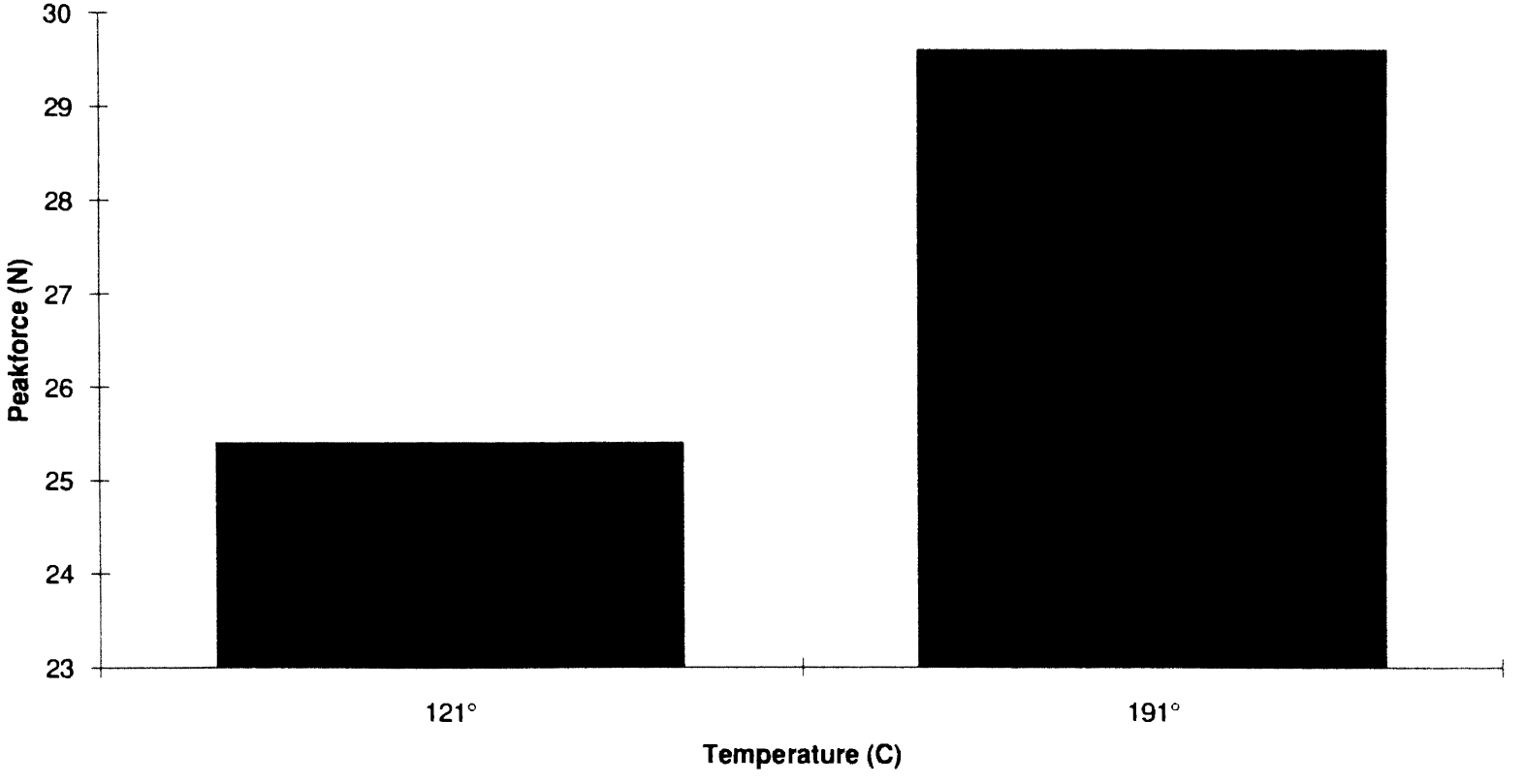
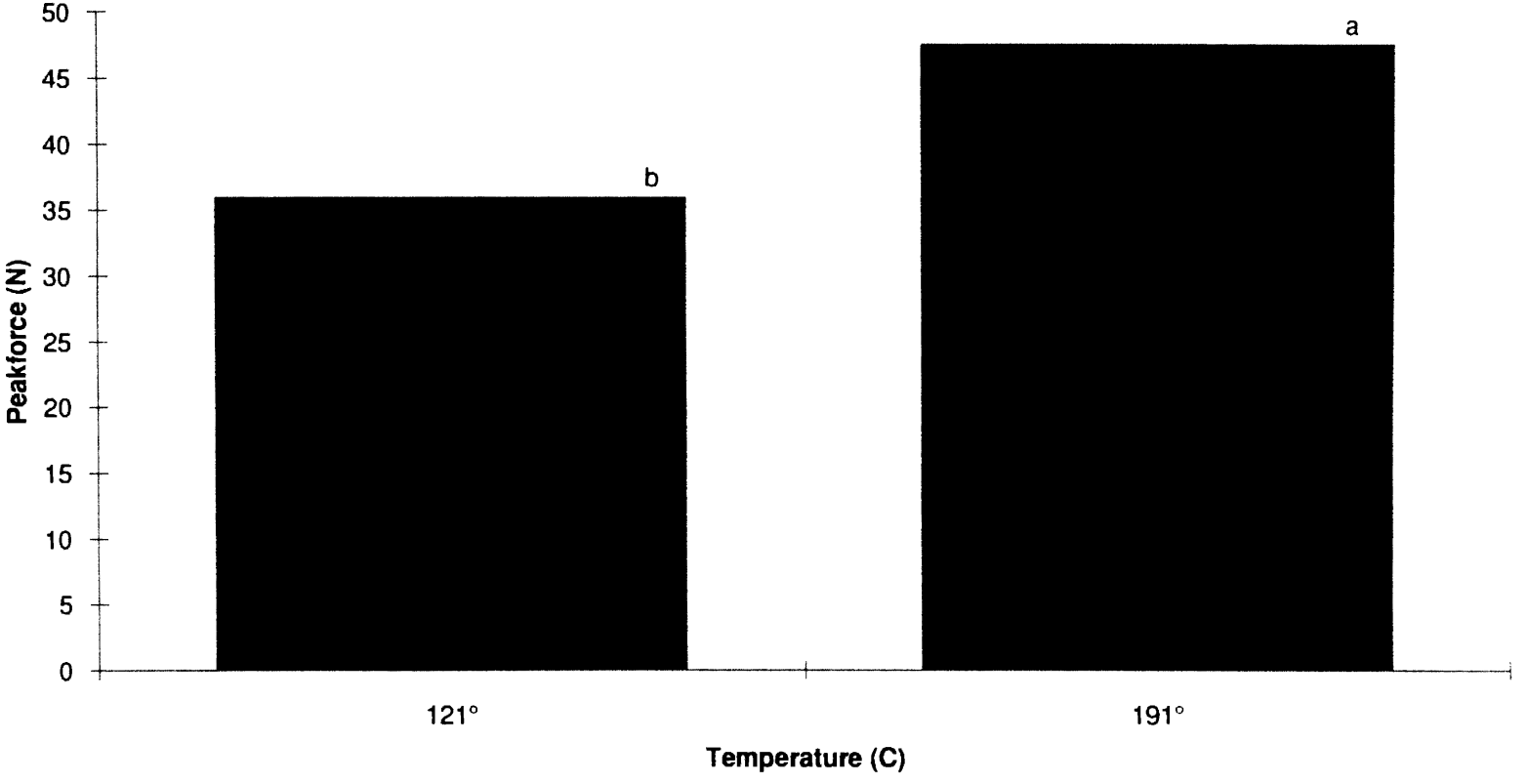


Figure 4.5 Effect of Temperature on the Peak Force Required to Shear Through Core Samples from Whole Muscle Roasts.



[ab] Means with like superscripts are not significantly different

Figure 4.6 Effect of Temperature on the Peak Force Required to Shear Through Samples from Restructured Roasts.

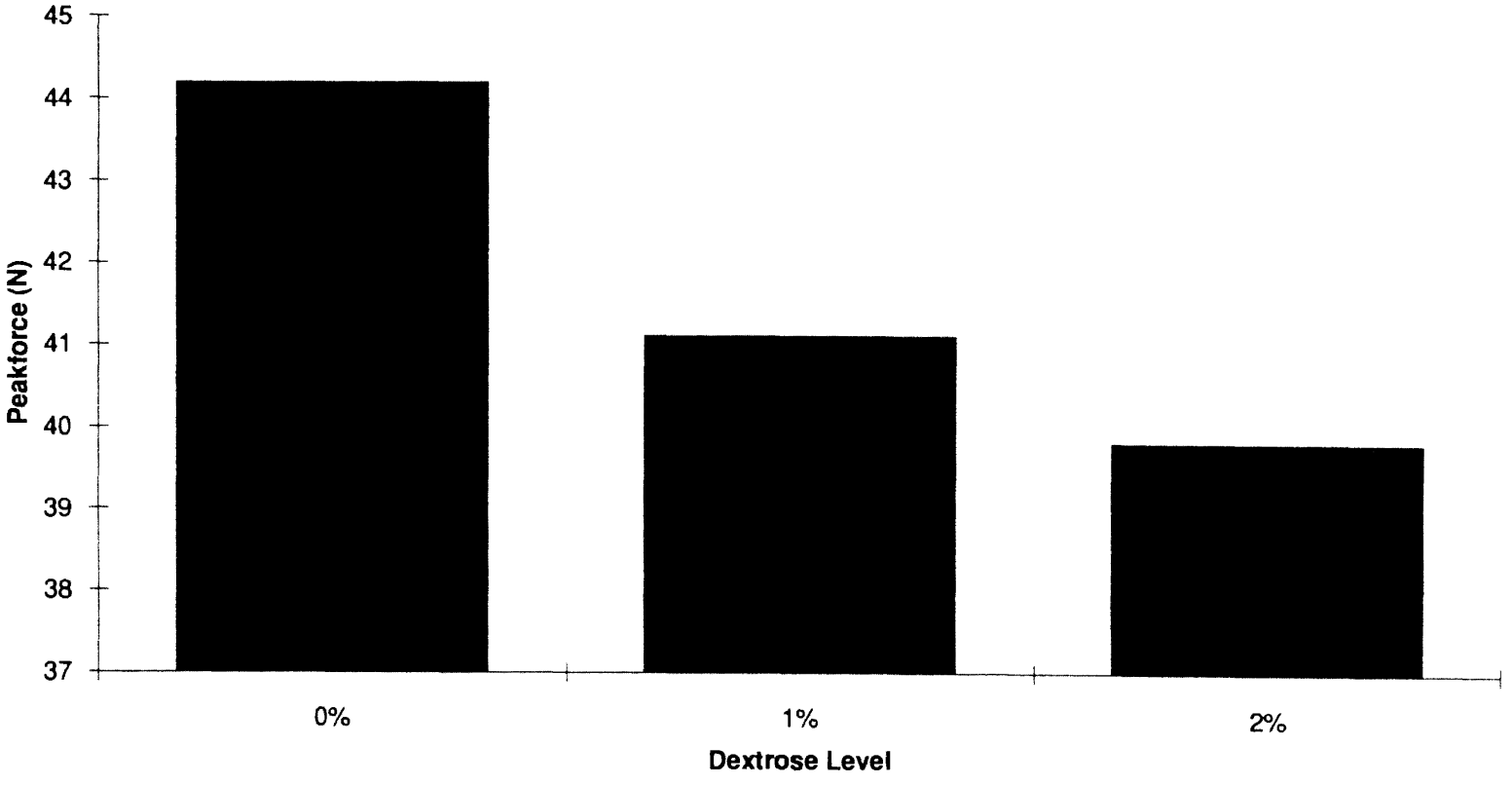
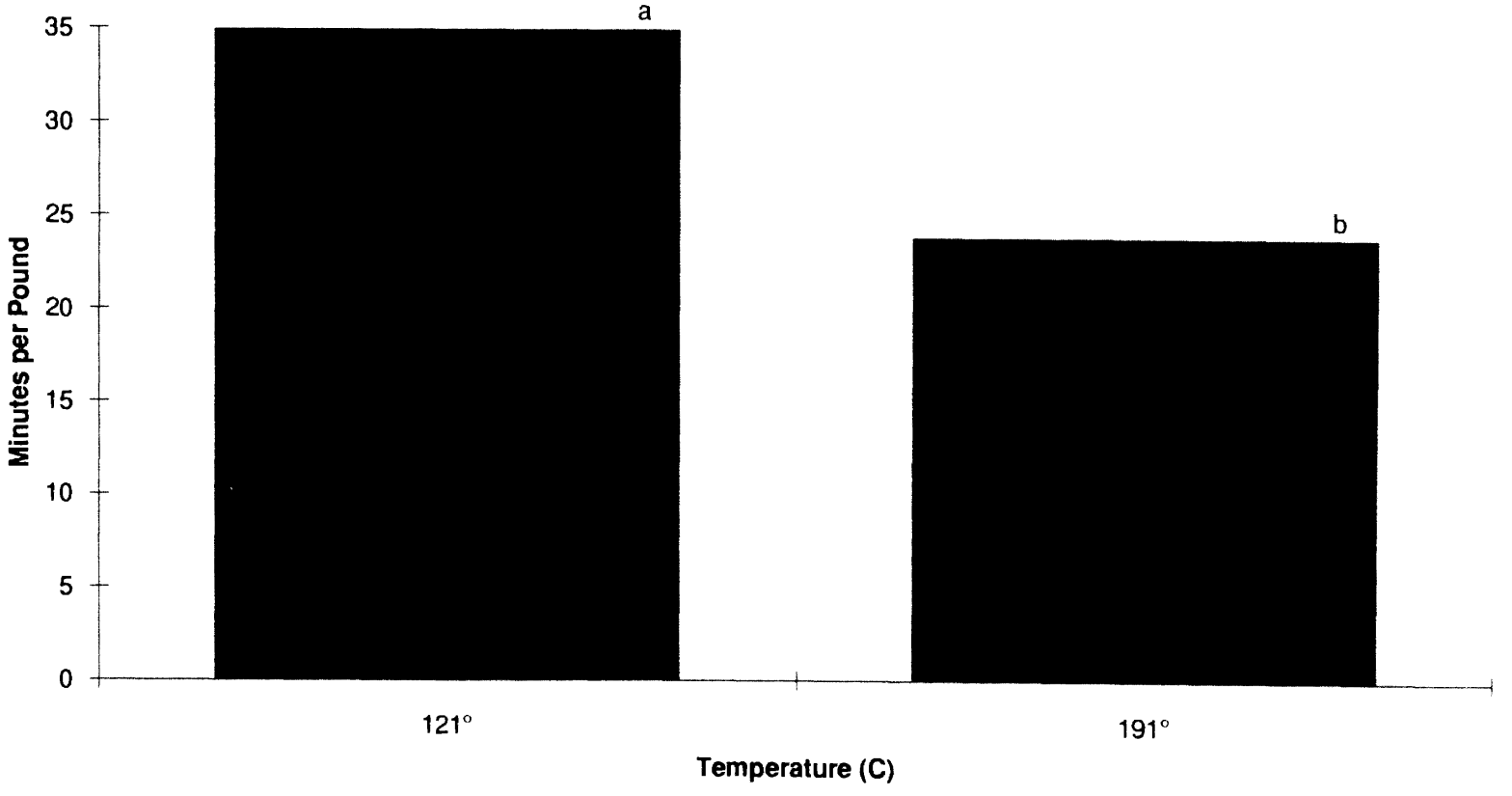
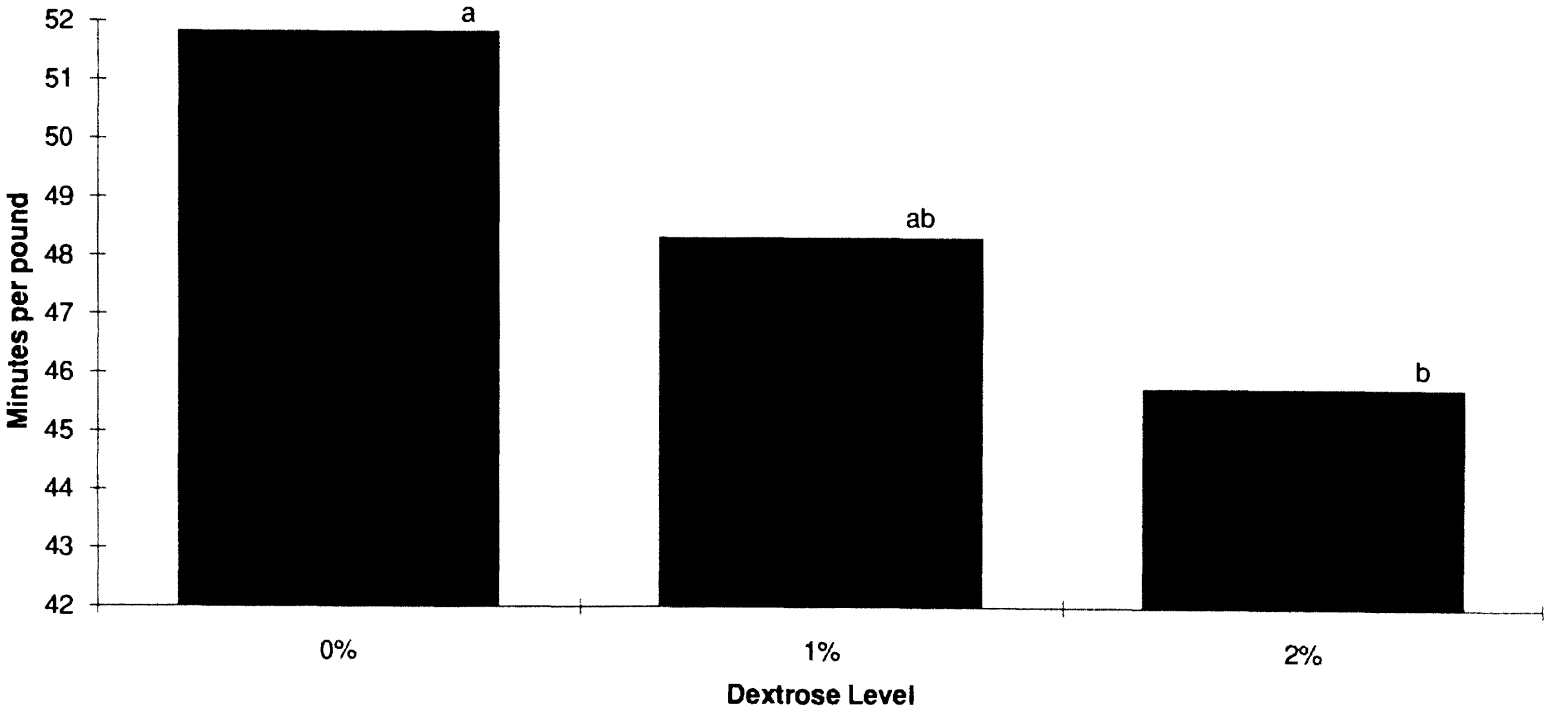


Figure 4.7 Effect of Dextrose Level on the Peak Force Required to Shear Through Samples from Restructured Roasts.



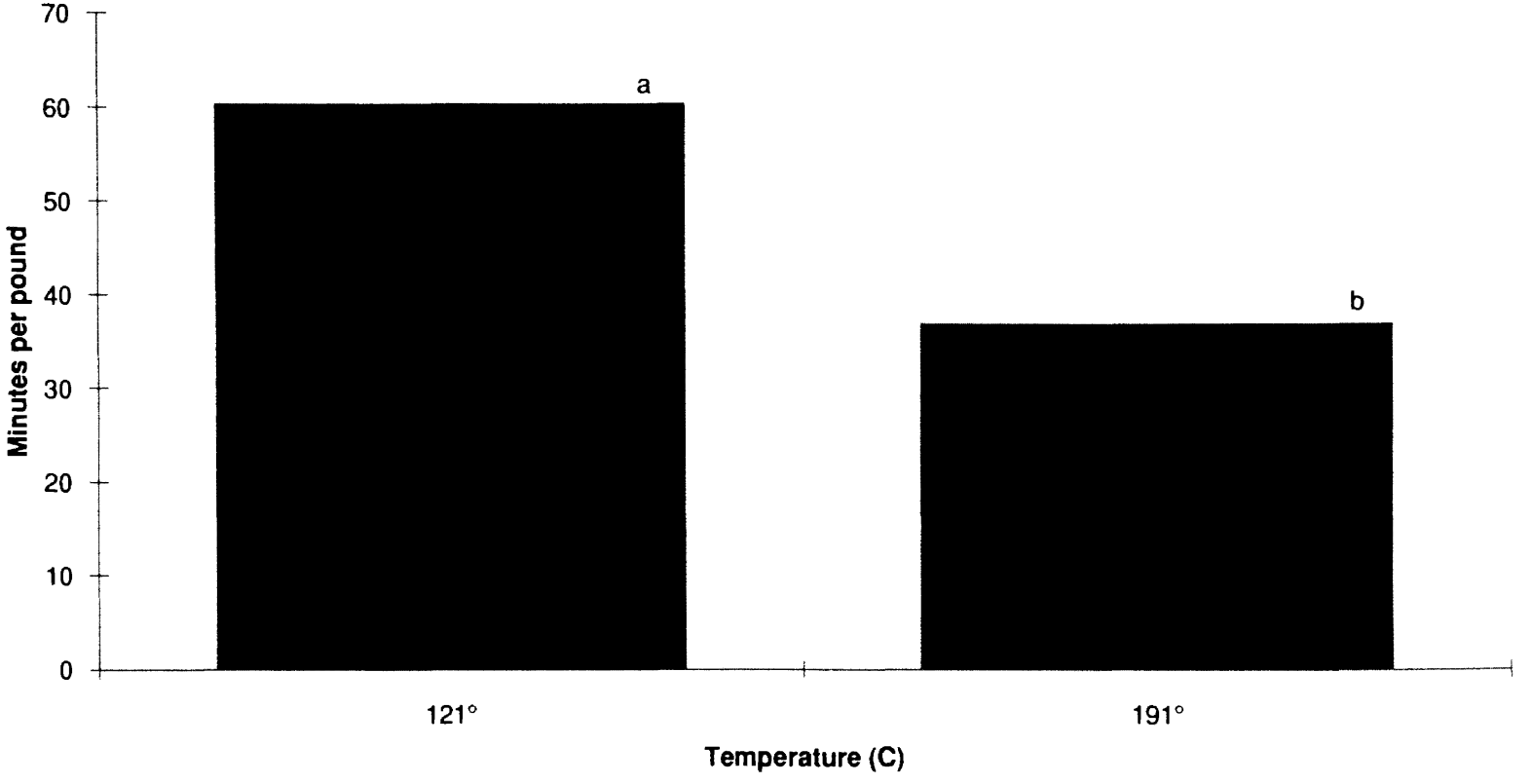
[ab] Means with like superscripts are not significantly different

Figure 4.8 Effect of Temperature on the Cooking Rate of Whole Muscle Roasts.



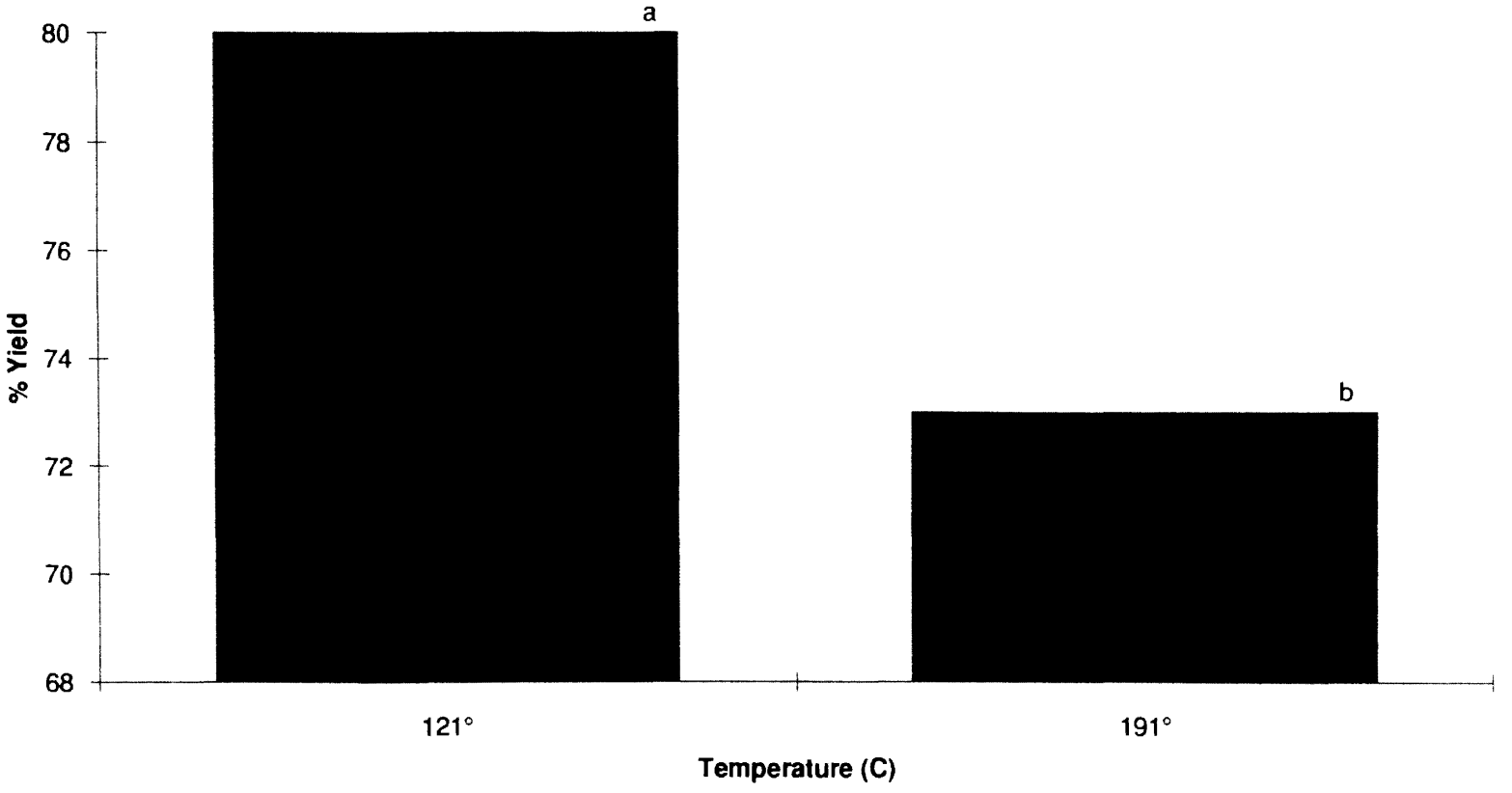
[ab] Means with like superscripts are not significantly different

Figure 4.9 Effect of Dextrose Level on the Cooking Rate of Restructured Roasts.



[ab] Means with like superscripts are not significantly different

Figure 4.10 Effect of Temperature on the Cooking Rate of Restructured Roasts.



[ab] Means with like superscripts are not significantly different

Figure 4.11 Effect of Temperature on the Cooked Yields of Both Whole Muscle and Restructured Roasts.

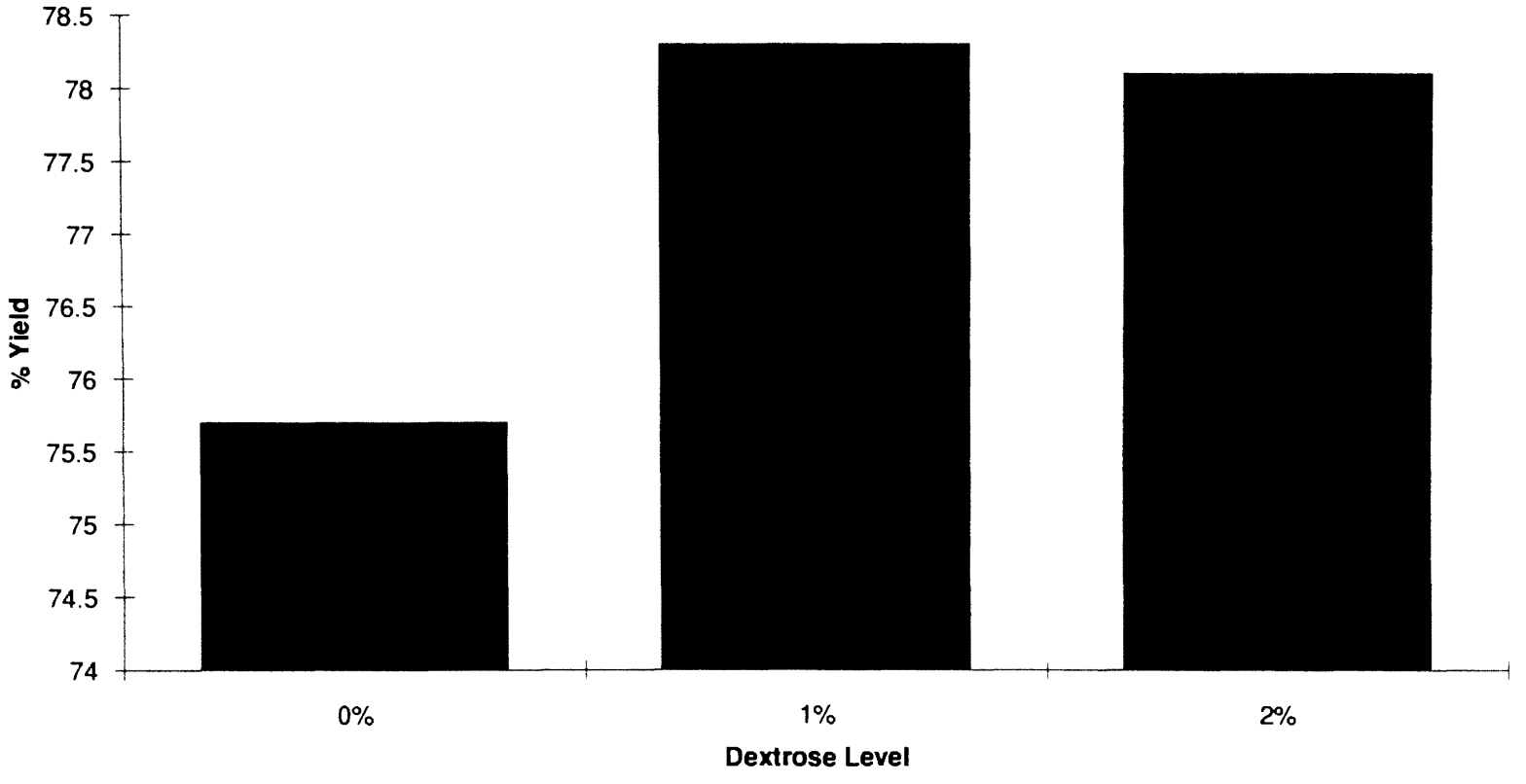


Figure 4.12 Effect of Dextrose Level on the Cooked Yields of Whole Muscle Roasts.

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